Practitioner's Docket No. 13189.143

CHAPTER II

Preliminary Classification:
Proposed Class: Unknown
Subclass: Unknown

TRANSMITTAL LETTER TO THE UNITED STATES ELECTED OFFICE (EO/US) (ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)

PCT/EP00/04264	10 May 2000 (10.05.00)	12 May 1999 (12.05.99)
International Application Number	**International Filing Date**	**International Earliest Priority Date**

TITLE OF INVENTION: DEVICE FOR DETERMINING THE THICKNESS OR THE NUMBER OF SHEETS OF A SHEET-LIKE OBJECT

APPLICANT(S): Griebel, Marion

ATTENTION: EO/US
Box PCT
Assistant Commissioner for Patents
Washington DC 20231

1. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. Section 371:

   a. This express request to immediately begin national examination procedures (35 U.S.C. Section 371(f)).

   b. The U.S. National Fee (35 U.S.C. Section 371(c)(1)) and other fees (37 C.F.R. Section 1.492) as indicated below:

CERTIFICATION UNDER 37 C.F.R. SECTION 1.10*
*(Express Mail label number is **mandatory**.)*
(Express Mail certification is optional.)

I hereby certify that this paper, along with any document referred to, is being deposited with the United States Postal Service on this date 11/8/01 in an envelope as "Express Mail Post Office to Addressee," mailing Label Number EV011001191US addressed to ATTENTION: EO/US, Box PCT, Assistant Commissioner for Patents, Washington, DC 20231.

Cheryl Martinez
(type or print name of person mailing paper)

Cheryl Martinez
Signature of person mailing paper

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2. Fees

CLAIMS FEE*	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS	17 -20 =	0	x $18.00 =	$0.00
	INDEPENDENT CLAIMS	1 - 3 =	0	x $84.00 =	$0.00
	MULTIPLE DEPENDENT CLAIM(S) (if applicable) + $280.00				$0.00
BASIC FEE	U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in Section 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in Section 1.445(a)(2) to the U.S. PTO: where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 C.F.R. Section 1.492(a)(5)) $890.00				$890.00
	Total of above Calculations				= $890.00
SMALL ENTITY	Reduction by 1/2 for filing by small entity, if applicable. Affidavit must be filed. (note 37 CFR Sections 1.9, 1.27, 1.28)				- $0.00
	Subtotal				$890.00
	Total National Fee				$890.00
	Fee for recording the enclosed assignment document $40.00 (37 C.F.R. Section 1.21(h)). See attached Recordation Cover Sheet Form PTO-1619.				$40.00
TOTAL	Total Fees enclosed				$930.00

*See attached Preliminary Amendment Reducing the Number of Claims.

Please charge Account No. 50-1848 in the amount of $930.00. A duplicate copy of this sheet is enclosed.

3. A copy of the International Application as filed (35 U.S.C. Section 371(c)(2)) is transmitted herewith.

4. A translation of the International Application into the English language (35 U.S.C. Section 371(c)(2)) is transmitted herewith.

5. Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. Section 371(c)(3)) have not been transmitted. Applicant chose not to make amendments under PCT Article 19.

Date of mailing of Search Report (from form PCT/ISA/220): 14 August 2000.

6. A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. Section 371(c)(3)) has not been transmitted for reasons indicated in Section 5.

7. A copy of the International Examination Report (PCT/IPEA/416) is transmitted herewith.

8. Annexes to the International Preliminary Examination Report are transmitted herewith.

9. A translation of the annexes to the International Preliminary Examination Report is transmitted herewith.

10. An oath or declaration of the inventor (35 U.S.C. Section 371(c)(4)) complying with 35 U.S.C. Section 115 is submitted herewith, and such oath or declaration identifies the application and any amendments under PCT Article 19 that were transmitted as stated in Section 3 and/or 5; and states that they were reviewed by the inventor as required by 37 C.F.R. Section 1.70.

II. Other document(s) or information included:

11. An International Search Report (PCT/ISA/220) or Declaration under PCT Article 17(2)(a) is transmitted herewith.

12. An Information Disclosure Statement under 37 C.F.R. Sections 1.97 and 1.98 will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. Section 371(c).

13. An Assignment document is transmitted herewith for recording. A Recordation Cover Sheet Form PTO-1619 is also transmitted herewith.

14. Additional documents:

a. International Publication No. WO 00/70305 (front page only)
b. First Preliminary Amendment (37 C.F.R. Section 1.121)
c. Final version of PCT/EP00/04264 for the prosecution at the USPTO to be filed as first preliminary amendment
d. Formal Drawings (4 sheets – 5 figures)
e. Annotated copy of Final version of PCT/EP00/04264
f. Express Mail Certificate
g. Return Postcard

15. The above items are being transmitted before 30 months from any claimed priority date.

AUTHORIZATION TO CHARGE ADDITIONAL FEES

The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the entire pendency of this application to Account No. 50-1848:

37 C.F.R. Section 1.492(a)(1), (2), (3), and (4) (filing fees)
37 C.F.R. Section 1.492(b), (c), and (d) (presentation of extra claims)
37 C.F.R. Section 1.17 (application processing fees)
37 C.F.R. Section 1.17(a)(1)-(5) (extension fees pursuant to Section 1.136(a))
37 C.F.R. Section 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 20 months after the priority date).

Date: Nov. 8, 2001

Signature of Practitioner
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
AS DESIGNATED/ELECTED OFFICE DO/EO/US

U.S. Patent Application No.: Applied For)
)
International Application No.: PCT/EP00/04264)
)
International Filing Date: 10 May 2000)
)
Priority Date: 12 May 1999)
)
For: Device For Determining The Thickness O)
The Number Of Sheets Of A Sheet-Like)
Object)
)
Applicant (Inventor):)
Marion Griebel)

Group Art Unit: Unknown

Examiner: Unknown

Docket No: 13189.143

ATTENTION: EO/US
BOX PCT
ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, DC 20231

November 7, 2001

Dear Sir:

FIRST PRELIMINARY AMENDMENT

In the Specification:

Please substitute the attached specification entitled "Final version of PCT/EP00/04264 for the prosecution at the USPTO to be filed as first preliminary amendment" for the original PCT specification.

In the Claims:

Please substitute the enclosed claims 1 – 17, on pages 18 – 22, inclusive, attached to the substitute specification, for original claims 1 – 22.

In the Abstract:

Please substitute the enclosed abstract, attached to the substitute specification on page 23 for the original abstract.

REMARKS

Applicant respectfully requests that the Examiner base the examination upon the attached substitute specification, claims, and abstract. An Annotated Copy Of Final Version Of PCT/EP00/04264 is enclosed showing the revisions made in the substitute specification, claims, and abstract.

The PCT specification, claims, and abstract have been revised to conform to U.S. requirements. It is believed that no new matter was introduced in revising the specification, claims, and abstract.

In view of the foregoing amendments, it is believed that the application, including claims 1 – 17, is in condition for allowance, and favorable action is respectfully requested. The Examiner is invited to contact the undersigned by collect telephone call to advance the prosecution in any respect.

No additional fee for this Preliminary Amendment is seen to be required. If any additional fee is required, please charge it to Deposit Account No. 50-1848.

Respectfully submitted,
PATTON BOGGS LLP

By: _____

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Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates in general to a device for determining the thickness or the number of sheets of a moving sheet-like object, and in particular to a device for determining the number of sheets in a stack of paper.

Description of Prior Art

Conventional devices for determining the thickness or the number of sheets of a sheet-like object are based in essence on two different methods.

On the one hand, there are some devices operating on a mechanical basis. With the aid of a lever operating a microswitch, the edge of the object, e.g. of a stack of sheets, is scanned. This method is in fact of simple construction, but it is unreliable and less suited for moving objects.

In contrast thereto, optoelectronic methods, such as e.g. passing light control, in which the object, e.g. paper, passes through a light barrier, are easier to evaluate. However, they are susceptible of errors as the light transmission changes for different objects, e.g. different kinds of paper or printed images, resulting in misinterpretation of the optical signal.

Both of the afore-mentioned methods of determining the thickness or the number of sheets of a moving sheet-like object, e.g. a stack of paper, thus entail in part considerable dis-

advantages concerning the handling, accuracy and reliability in particular with moving sheet-like objects.

Additional methods, such as the distance measurement by inductive and capacitive sensors, do not result in accurate and reliable measurement of the thickness of a sheet-like object either and often are also less suited for measuring the thickness especially of moving sheet-like objects.

DE 3934623 A1 describes a device for folding specimens to be folded, e.g. folding specimens of paper, using an adjustable folding pressure, in particular for simultaneously measuring the thickness and the compressibility of the folding specimens. The thickness of folding specimens of paper can be determined by way of the folding pressure.

DE 3612914 A1 discloses a device for measuring the thickness of paper or the like, in which the paper rests on a support, and a movably supported sensor is provided which is responsive to the position of the surface of the paper and which is carried by an air cushion; the position of said sensor and thus the thickness of the paper can be determined by a measurement device.

DE 3922992 C2 discloses a means for recognizing both the thickness and the edges of recording media in processing apparatus, in particular in printers, in which the recording media rest on a support with an as small gap as possible and are adapted to be scanned by a sensing element measuring the lift and performing a relative movement with respect to the recording medium, with measured lift differences being converted to electrical signals representing the thickness of the recording media.

EP 0635696 B1 describes a device for the electronic measurement of the thickness of thin webs or sheets, in particular foils, films or paper sheets, consisting of a fixed support-

ing surface and a tactile sensor arranged in fixed manner and substantially perpendicularly to this supporting surface and having a ferromagnetic tactile member which is movable relative to the supporting surface and, as a function of its position relative to the supporting surface, influences the signal of an inductive transducer in the form of a sensor coil and thus indicates the thickness of the webs or sheets.

DE 19537340 A1 describes a page sensor apparatus for producing a signal related to a thickness of a sheet of paper, which comprises a base plate and a foot plate positioned in opposed relation. The base and foot plates are arranged to allow the paper to pass therebetween, so that the base and foot plates are separated by a distance substantially equal to the thickness of the sheet of paper. A capacitance sensing means connected to the base plate and the foot plate senses changes in the electrical capacitance of the base and foot plates and generates an output signal related to the plate separation and thus the paper thickness.

EP 0442727 A2 discloses a paper thickness detecting apparatus comprising an electrode detecting unit constituted by a ground electrode and an opposing detecting electrode arranged in upper and lower positions of a running path of paper, an oscillating circuit for generating an oscillation frequency signal, a resonant circuit for shifting a resonant point in response to a change in electrostatic capacitance corresponding to a change in paper thickness detected by the electrode detecting unit, and a detecting circuit for detecting an output signal of said resonant circuit in order to determine the thickness of the paper.

US 5,012,248 describes a device for determining the thickness of radar absorption material coatings. The device comprises a radiating element assembly for transmitting RF energy and recovering reflected RF energy from the coating. A source of a frequency-modulated RF signal comprises an FM ramp generator

assembly, a buffer amplifier assembly and a Gunn oscillator. A ferrite circulator directs the modulated RF signal to the radiating element assembly and the reflected RF energy to a detector assembly. The detector assembly includes a Schottky detector, a video amplifier assembly, a converter/driver assembly and a digital display, and is adapted to sense the reflected RF energy from the coating and provide a visual display in the form of a voltage that is inversely proportional to the amount of the reflected RF energy and is a measure for the thickness of the radar absorption material coating.

US 4,161,731 discloses an FM radar for the measurement of coal thickness wherein an FM transmitter is modulated by the combination of two signals; a horn-type antenna is used, which is filled with a material having a dielectric constant approximating that of coal, the antenna being positioned flush against the coal.

US 5,145,560 discloses a method and a device for determining the liquid jet velocity in a paper making machine. This jet velocity is detected by microwave Doppler-effect velocity sensors. The velocity sensors comprise a means for directing the microwave signal towards a first location of the liquid jet and for receiving the reflected microwave signal from the liquid jet, the velocity sensors including furthermore a means for generating a sensor output signal which is shifted in frequency in accordance with the velocity of the jet at the first location in accordance with the Doppler effect.

DE 3327526 A1 describes a method of determining the wall thickness or acoustic velocity of workpieces by means of an ultrasonic measuring instrument. The ultrasonic measuring instrument comprises two transducer elements accommodated in a common housing, a transmit transducer and a receive transducer that are acoustically isolated from each other and receive and transmit the ultrasonic signals. The transmit element is coupled to a transmitter, and the receive element is

coupled to a receiver connected to an evaluation unit. On the basis of the travel time of the signal of the transmit transducer reflected from a wall or a workpiece and received in the receive transducer, the evaluation unit determines the workpiece properties, such as the wall thickness or the acoustic velocity of the wall material. The evaluation unit moreover, by means of correction factors, performs corrections on the thickness or travel time measured by the ultrasonic measuring instrument, in accordance with the type of probe used. These correction factors are retrieved by the evaluation unit from a memory (PROM) which furthermore is adapted to store the thickness of a calibration body mounted on the measuring instrument, previously measured thickness values or preset values for measuring a thickness differential. For determining a thickness differential from a previously measured thickness or a predetermined thickness, a comparison means in the form of a comparator may be connected to the evaluation unit. The ultrasonic measuring instrument can also perform thickness measurements during movement relative to an object to be measured, e.g. a wall.

The document WO82/03455 A1 describes a method and a device for measuring layer the thickness of material layers using a frequency-modulated ultrasonic signal. The ultrasonic signal is modulated with a specific, fixed modulation rate and directed to a material layer to be measured. Due to the reflection of the signal on the outer and inner boundary layer of the material, interference of these reflected signals occurs, and the receive signal received by the layer, due to the frequency modulation of the ultrasonic signal transmitted to the layer, thus has a frequency-dependent interference pattern having maxima and minima, which may be used for determining the thickness of the material layer.

DE 3424652 A1 discloses an apparatus for dynamically determining the local weight per unit area of sheet-like material. The apparatus comprises an arrangement of transmitter, re-

ceiver and material to be measured, in which the portions of sound reflected on these elements are faded out of the path of rays between the transmitter and the receiver and at the same time prevents by suitable means, e.g. sound traps, that the faded out portions of sound return to the original path of rays and reach the transmitter and/or receiver. The material to be measured is in the form of sheets and is moved between transmitter and receiver with the aid of guide means, e.g. transport rollers. The sheet-like material to be measured is exposed to sound waves from a sound transmitter, and the portions of sound transmitted and reflected by the material to be measured are measured with the aid of a receiver in order to determine therefrom the weight per unit area.

DE 4141446 C2 describes a method of measuring the thickness of a film of water, snow or ice on a surface, in which a pulse of electromagnetic radiation is directed obliquely from above onto the surface covered with such film. The transition time of the pulse through the film and thus the thickness of the layer are determined by a transition time difference measured in the receiver between a portion of the pulse reflected back to the receiver at the surface of the film and another portion of the pulse reflected back to the receiver at the surface on which said film is located. In a different process, the transition time of a pulse between the transmitter, the surface covered by a film, and the receiver is measured and stored, and this stored transition time is compared with a transition time of a momentarily measured transition time value for a pulse transmitted by the transmitter and reflected at the surface of a film located on the surface and received in the receiver, and the thickness of the film is determined on the basis of this comparison.

A disadvantage of the conventional devices for determining the thickness of and the number of sheets of a sheet-like object resides in that they do not permit accurate and reliable determination of the thickness and in particular of the num-

ber of sheets of a moving sheet-like object, such as a stack of paper.

A further disadvantage of the conventional devices consists in that no non-contacting and at the same time accurate detection of the thickness or of the number of sheets is possible.

Still another disadvantage of the conventional devices consists in that in particular the determination of the thickness or the number of sheets of moving objects, in which e.g. the individual sheets form a loose stack of paper and which are moved on arbitrary guide paths at different velocities, is not possible in accurate and reliable manner.

SUMMARY OF THE INVENTION

It is the object of the present invention to provide a device for determining the thickness or the number of sheets of a sheet-like object, which renders possible an accurate, reliable and non-contacting determination of the thickness or the number of sheets of a sheet-like object.

This object is met by a device for determining the thickness or the number of sheets of a sheet-like object, comprising:

a transmitting and receiving device for transmitting radiation to the object, for receiving reflected radiation containing at least the part of the radiation transmitted to the object that is reflected by the object, and for generating a signal representing the reflected radiation; and

an evaluator for determining the thickness or number of sheets of the object, which receives the signal representing the reflected radiation, wherein the evaluator comprises:

a memory for storing a plurality of previously determined time signal patterns or a plurality of previously determined frequency spectra or a plurality of previously determined area values of frequency spectra, which are each associated with a specific thickness or number of sheets of the object; and

a comparator for comparing the signal representing the reflected radiation or a frequency spectrum derived therefrom or an area value of a frequency spectrum derived therefrom, to the time signal patterns or frequency spectra or area values of frequency spectra which are stored in the memory and for determining the thickness or the number of sheets of the sheet-like object as a result of the comparison.

The invention, among other things, is based on the finding that the movement of a sheet-like object in accordance with the velocity and the thickness or the number of sheets thereof, respectively, has a different effect, in the instant case also via the Doppler effect, on the characteristics of the reflected portion of radiation directed onto the moving sheet-like object, e.g. microwave radiation, and that thus a determination of the thickness of the moving object or of the number of sheets, respectively, is rendered possible by virtue of predetermined connections between the radiation characteristics and the thickness of the object or the number of sheets.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will be elucidated in more detail hereinafter with reference to the accompanying drawings in which

Fig. 1 shows a device for determining the thickness or the number of sheets of a moving sheet-like object ac-

cording to a first preferred embodiment of the present invention;

Fig. 2 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a second preferred embodiment of the present invention;

Fig. 3 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a third preferred embodiment of the present invention;

Fig. 4 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a fourth preferred embodiment of the present invention; and

Fig. 5 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a fifth preferred embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A first preferred embodiment of the present invention will be described in the following with reference to Fig. 1. A device for determining the thickness or the number of sheets of a moving sheet-like object 100 according to the first embodiment of the present invention comprises a transmitting and receiving device 102, such as a microwave sensor having a waveguide antenna 118, or an ultrasonic sensor or an electromagnetic sensor in general or an acoustic sensor. The transmitting and receiving device 102 transmits radiation to the moving object 100, such as a paper or stack of paper, and receives reflected radiation comprising at least that part of the radiation transmitted to the object that is reflected by

the moving sheet-like object 100. In response to receipt of the reflected radiation, the transmitting and receiving device 102 furthermore generates a signal representing this reflected radiation. The device for determining the thickness or the number of sheets of a moving sheet-like object 100 according to the first embodiment of the present invention comprises furthermore an evaluation means 104 determining the thickness of the moving object on the basis of previously determined relationships or connections between signal characteristics and the thickness of the moving object 100.

The radiation emitted by the transmitting and receiving device 102 is scattered by the moving object 100, e.g. sheets of paper, and is reflected back to the transmitting and receiving device 102. The reflected radiation has a shifted frequency with respect to the transmitted radiation due to the Doppler effect. Depending on the type of object, e.g. the type of paper and the thickness of the paper, but also the position and velocity of the moving object, a signal pattern or curve is obtained which, in the time and frequency domain, is characteristic of the paper thickness or the number of sheets of the paper supplied simultaneously in superimposed manner. These signals can be digitized, for example, in the evaluation means 104, supplied to a calculating unit and analyzed there by mathematical auxiliary means.

In the first embodiment of the present invention, the evaluation means 104 comprises a first storage means 106 for storing one or more previously determined time patterns each associated with a specific thickness of the moving object 100. The previously determined time patterns may be determined, for example, empirically by measuring the reflected radiation of a moving object 100 with different thickness or number of sheets, but also e.g. with a different velocity, position etc.. These characteristic time patterns then are stored in the first storage means 106, e.g. a RAM, of a fixed disc or another storage medium in order to render possible in a prac-

tical application later on a comparison with actually measured signal patterns or curves and determine the thickness of object 100 on the basis of this.

In the first embodiment of the present invention, evaluation means 104 comprises furthermore a first comparison means 108 for comparing the time pattern of the signal representing the reflected radiation to the stored, previously determined time patterns and for determining the thickness of the moving object 100 on the basis of the comparisons. This comparison means 108, for example, is capable of retrieving from the first storage means 106 those previously determined characteristic time patterns that are associated with a specific thickness of the moving object in order to compare the same to the actually measured time patterns of the signal representing the reflected radiation. This renders possible a thickness determination by way of the time signal. The first comparison means 108 may be e.g. a fuzzy logic, any other statistical logic, a means carrying out integral value comparisons of integrals of the signals, signal curve comparisons etc.. The first comparison means 108, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A second preferred embodiment of the present invention will be described in the following with reference to Fig. 2. In the second embodiment of the present invention, an evaluation means 204 comprises a transformation means 210 for transforming the time pattern of the signal representing the reflected radiation to the frequency domain, in order to generate a frequency spectrum of the reflected radiation received by a transmitting and receiving device 202. The time pattern can be read, for instance, into a memory, retrieved from the memory and can be transformed to the frequency domain e.g. by means of transformation means 210, such as a means for performing a Fourier transform, to thus obtain a frequency spec-

trum. This frequency spectrum again can be stored in a memory for carrying out a comparison later on. However, the frequency spectrum can also be determined directly from the time pattern and then processed further or stored.

In the second embodiment of the present invention, the evaluation means 204 comprises furthermore a second storage means 202, e.g. a RAM, a fixed disc or another storage medium, for storing one or more previously determined frequency spectra each associated with a specific thickness of a moving object 200. These previously determined frequency spectra may be determined, for example, empirically by tests in which the time signals for objects of different thickness, e.g. of stacks of sheets with different numbers of sheets, but also e.g. with a different velocity, position etc. are determined and transformed to the frequency domain. These frequency spectra then are assigned to, or characteristic of, a specific thickness or number of sheets of a moving object 200 having a specific velocity, a specific position etc..

In the second embodiment of the present invention, evaluation means 204 comprises furthermore a second comparison means 208 for comparing the frequency spectrum of the reflected radiation to the stored, previously determined frequency spectrum and for determining the thickness of the moving object 200 on the basis of the comparisons. In doing so, the previously determined frequency spectra, each corresponding to a specific thickness of object 200, are compared to the frequency spectra of signals actually measured by the transmitting and receiving device 202, which correspond to the reflected radiation, in order to thus determine the thickness of object 200. The second comparison means 208 may be e.g. a fuzzy logic, any other statistical logic, a means carrying out integral value comparisons of integrals of the spectra, spectrum pattern comparisons etc.. The second comparison means 208, both in terms of hardware and in terms of software, may be imple-

mented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A third preferred embodiment of the present invention will be described in the following with reference to Fig. 3. In the third embodiment, an evaluation means 304, in addition to a transformation means 310 identical to the afore-described transformation means 210 of the second embodiment of Fig. 2, comprises a third storage means 306 for storing one or more previously determined area values each associated with a specific thickness of a moving object 300, as well as an area determination means 312 for determining the area of the spectrum delivered by transformation means 310 in the region of a specific frequency, e.g. the Doppler frequency, of the reflected radiation.

During movement of the moving object 300, the part of the radiation reflected by the moving object 300 is shifted in its frequency with respect to the frequency of the transmitted radiation due to the Doppler effect. The frequency transform of the signal or time pattern corresponding to the reflected radiation has a peak value in the region of that frequency that results from the Doppler shift of the transmission frequency of the signal. Around this frequency component, there may be performed an integration or area determination by area determination means 312, since the area in the transform, e.g. the Fourier transform, of the Doppler frequency is a measure for the intensity of the reflection and thus for the question whether, for example, with a sheet-like input or output object of a printer, copier or facsimile device etc., only one sheet or a plurality of sheets have been drawn in or output. The area values can be determined empirically for different configurations of the object, in particular in accordance with the thickness, but in addition also in accordance with the velocity, position, guiding of the object in a device etc., and can be stored in a memory e.g. in the form of tables, in order to be able later on to determine the

thickness of a moving object 300 that is moved with a specific velocity etc., directly by way of comparisons of the actual area values output by the area determination means 312 to the stored characteristic area values.

In the third embodiment of the present invention, evaluation means 304 comprises furthermore a third comparison means 308 for comparing the area determined by the area determination means 312 to the stored, previously determined area values and for determining the thickness of the moving object 300 on the basis of the comparisons. The third comparison means 308 may be e.g. a fuzzy logic or any other statistical logic etc., and, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A fourth preferred embodiment of the present invention will be described in the following with reference to Fig. 4. The device for determining the thickness or the number of sheets of a moving sheet-like object 400 according to the fourth embodiment comprises a transmitting and receiving means 402 and an evaluation means 404 which, as in the third embodiment, comprises a transformation means 410 and an area determination means 412, and in addition first, second and/or third storage means 406a, 406b and 406c, respectively, first, second and/or third comparison means 408a, 408b and 408c, respectively, and optionally a fourth comparison means 414. The first, second and third storage means 406a, 406b and 406c, respectively, correspond to the first, second and third storage means 106, 206, 306 of the first, second and third embodiments of Figs. 1, 2 and 3, and the first, second and third comparison means 408a, 408b and 408c, respectively, correspond to first, second and third comparison means 108, 208, 308 of the first, second and third embodiments of Figs. 1, 2 and 3.

The first, second and third comparison means 408a, 408b and/or 408c may be coupled to comparison means 414, e.g. a fuzzy logic, for examining the conformity of the thickness values determined by the first, second and/or third comparison means 408a, 408b, 408c and for determining a most probable thickness of the moving object 400. This permits still safer determination of the thickness of the moving object 400, e.g. the number of sheets of a stack of paper.

The outputs 120, 220, 320, 420a, 420b, 420c, 422 of the comparison means 108, 208, 308, 408a, 408b, 408c, 414 of the first, second, third and fourth embodiments may be, for example, binary signals having a specific bit width, which code the thickness or the number of sheets of the moving sheet-like object or provide information as to which most probable thickness or number of sheets the moving object, e.g. a stack of paper consisting of sheets, has.

In a fifth preferred embodiment of the present invention, the device for determining the thickness or the number of sheets of a moving sheet-like object 500 comprises furthermore a reflector 516 which, with respect to a transmitting and receiving device 502 is arranged behind the moving object 500 and which reflects the radiation transmitted through the moving object 500 to the moving object 500 and to the transmitting and receiving device 502. This reflector 516 has the effect that the radiation reflected to the transmitting and receiving device 502 contains the radiation reflected by reflector 516 in addition to the radiation reflected by the moving object 500. This yields a mixed signal which, similar to the statements made hereinbefore, can be processed by an evaluation means 504 and analyzed to determine the thickness of the moving object 500.

By means of the device for determining the thickness and the number of sheets of a sheet-like object according to any of the preceding embodiments it is possible furthermore to meas-

ure the thickness or the number of sheets of a non-moving object.

In a first embodiment this is possible by moving the device or the transmitting and receiving device, respectively. In doing so, for example the transmitting and receiving device is moved on a platform preferably over small distances, e.g. in an oscillating motion, towards the object and away from the object. This movement can be generated, for example, by an oscillation generating member, e.g. a piezoelectric member, mechanical oscillation generating members etc.. However, it is also possible to vary the focusing or the form of the radiation used in order to simulate this movement. This can be effected e.g. by means of lenses, diaphragms etc.. Moreover, mirror elements or deflection means altering the beam travel length, such as mirrors arranged in the direction of the beam, may be utilized to alter the travel lengths of the radiation and thus simulate a movement.

In a second embodiment, there is, for example, neither a movement of the transmitting and receiving device nor of the object, and only the signal form received by the object, e.g. the time signal of the reflected radiation, is detected. This reflected signal, in terms of its width and form, is dependent upon the number of layers or sheets of the sheet-like object, since the signal portions reflected on these layers have different travel-back times to the receiving device and thus broaden the reflected signal e.g. in terms of time. On the basis of the width, it is then possible to determine the number of sheets or the thickness of the object. The reflected signal can be processed in various ways, as elucidated hereinbefore in connection with the previous embodiments, and can be compared to stored experimental values for reflected signals associated with different object thickness values. By statistical evaluation of the signal form received and of signal forms, stored or determined or learned during operation, which are associated with different thickness val-

ues, the thickness of an object can be determined simply and rapidly.

The device for determining the thickness or the number of sheets of a moving sheet-like object or of a sheet-like object according to the present invention renders possible facilitated handling without operational elements. Software analysis of the characteristic signals, spectra, areas permits e.g. arbitrary accuracy, thereby increasing reliability to a high degree as well. The device of the present invention furthermore renders possible a simple construction, improved evaluation possibilities, is based on a non-contacting process and is flexibly applicable to various configurations, e.g. in paper manufacture, paper processing and paper handling. It may be employed e.g. in the utilization of microwave radiation with all sheet-like objects having a thickness between 1/10 mm and some millimeters.

What is claimed is:

1. A device for determining the thickness or the number of sheets of a sheet-like object, comprising:

- a transmitting and receiving device for transmitting radiation to the object, for receiving reflected radiation containing at least the part of the radiation transmitted to the object that is reflected by the object, and for generating a signal representing the reflected radiation; and

- an evaluator for determining the thickness or number of sheets of the object, which receives the signal representing the reflected radiation,

wherein the evaluator comprises:

- a memory for storing a plurality of previously determined time signal patterns or a plurality of previously determined frequency spectra or a plurality of previously determined area values of frequency spectra, which are each associated with a specific thickness or number of sheets of the object; and

- a comparator for comparing the signal representing the reflected radiation or a frequency spectrum derived therefrom or an area value of a frequency spectrum derived therefrom, to the time signal patterns or frequency spectra or area values of frequency spectra which are stored in the memory and for determining the thickness or the number of sheets of the sheet-like object as a result of the comparison.

2. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1, wherein

the memory comprises a first memory for storing one or more previously determined time signal patterns each associated with a specific thickness of the object; and

the comparator comprises a first comparator for comparing the time signal pattern of the signal representing the reflected radiation to the stored previously determined time signal patterns and for determining the thickness of the object on the basis of the comparisons.

3. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1, wherein the evaluator further comprises:

a transformator for transforming the time signal pattern of the signal representing the reflected radiation to the frequency domain in order to generate a frequency spectrum of the reflected radiation.

4. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 3, wherein the transformator carries out a Fourier transform.

5. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 3, wherein the evaluator comprises furthermore:

a frequency spectra memory for storing a plurality previously determined frequency spectra each associated with a specific thickness of the object; and

a second comparator for comparing the frequency spectrum of the reflected radiation to the stored previously determined frequency spectra and for determining the thickness of the object on the basis of the comparisons.

6. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 3, wherein the evaluator comprises furthermore:

an area value memory for storing a plurality of previously determined area values each associated with a specific thickness of the object;

an area determinator for determining the area of the spectrum around the frequency corresponding to the Doppler shift of the frequency of the frequency of the radiation transmitted to the object; and

a third comparator for comparing the area determined to the stored, previously determined area values and for determining the thickness of the object on the basis of the comparisons.

7. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1, comprising furthermore a reflector which, with respect to the transmitting and receiving device, is disposed behind the object and which reflects the radiation transmitted through the object to the object and to the transmitting and receiving device.

8. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1, wherein the comparators comprise a fuzzy logic.

9. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1,

wherein the comparators are coupled to a fourth comparator for examining the conformity of the thicknesses determined by the comparators and for determining a most probable thickness of the object.

10. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 9, wherein the fourth comparator is a fuzzy logic.

11. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1, wherein the radiation is electromagnetic or acoustic radiation.

12. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 11, wherein the radiation is microwave radiation.

13. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 11, wherein the transmitting and receiving device comprises a waveguide antenna.

14. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 11, wherein the radiation is ultrasonic radiation.

15. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 1, wherein the object is a moving stack of sheets and the thickness of the moving stack of sheets is a measure for the number of media.

16. A device for determining the thickness or the number of sheets of a moving sheet-like object according to claim 15, wherein the moving stack of sheets is a stack of paper.

17. A device for determining the thickness or the number of sheets of a sheet-like object according to claim 15, wherein the transmitting and receiving device is in motion instead of the object.

ABSTRACT

A device for determining the thickness or the number of sheets of a sheet-like object has a transmitting and receiving device for transmitting radiation to the object, for receiving reflected radiation containing at least the part of the radiation transmitted to the object that is reflected by the object, and for generating a signal representing the reflected radiation. An evaluator is provided for determining the thickness or number of sheets of the object, which receives the signal representing the reflected radiation. The evaluator has a memory for storing a plurality of previously determined time signal patterns or a plurality of previously determined frequency spectra or a plurality of previously determined area values of frequency spectra, which are each associated with a specific thickness or number of sheets of the object, and a comparator for comparing the signal representing the reflected radiation or a frequency spectrum derived therefrom or an area value of a frequency spectrum derived therefrom, to the time signal patterns or frequency spectra or area values of frequency spectra which are stored in the memory and for determining the thickness or the number of sheets of the sheet-like object as a result of the comparison.

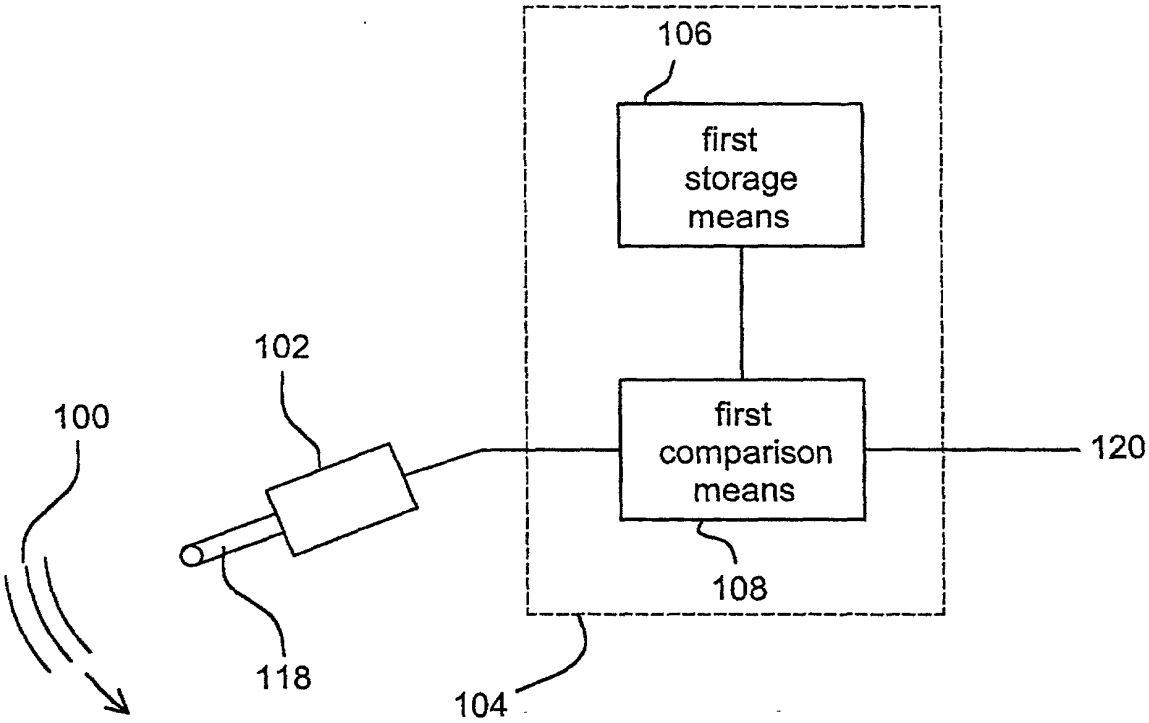
106
first storage means
102
100
first comparison means
120
108
118
104

Fig. 1

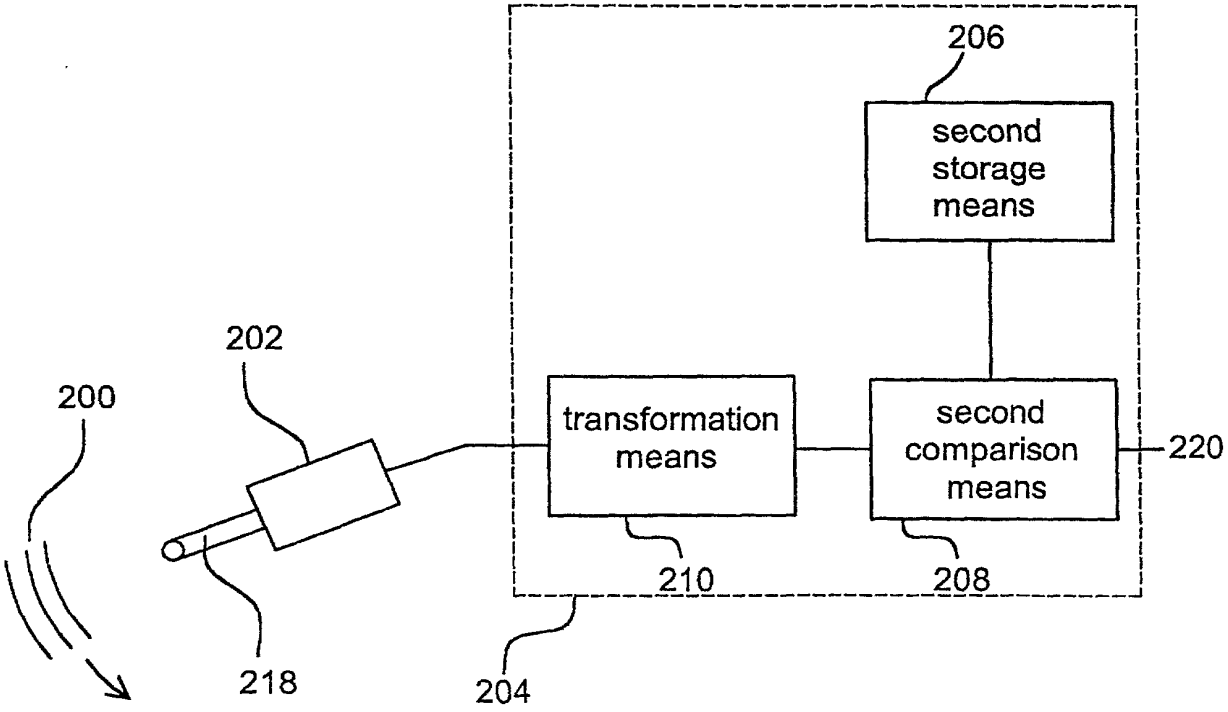
206
second storage means
202
200
transformation means
second comparison means
220
210
208
218
204

Fig. 2

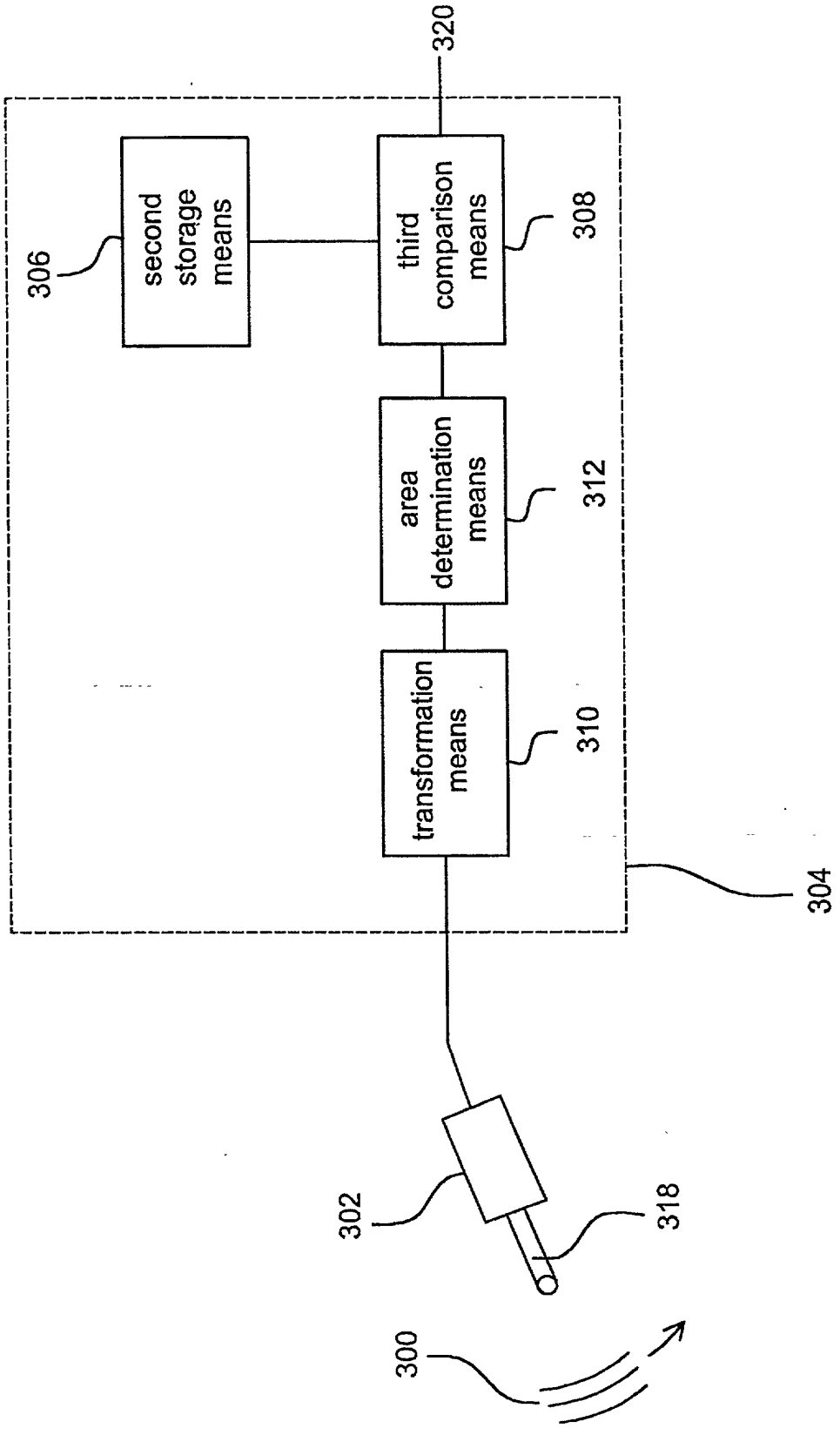
320
second storage means
306
third comparison means
308
area determination means
312
transformation means
310
304
302
318
300

Fig. 3

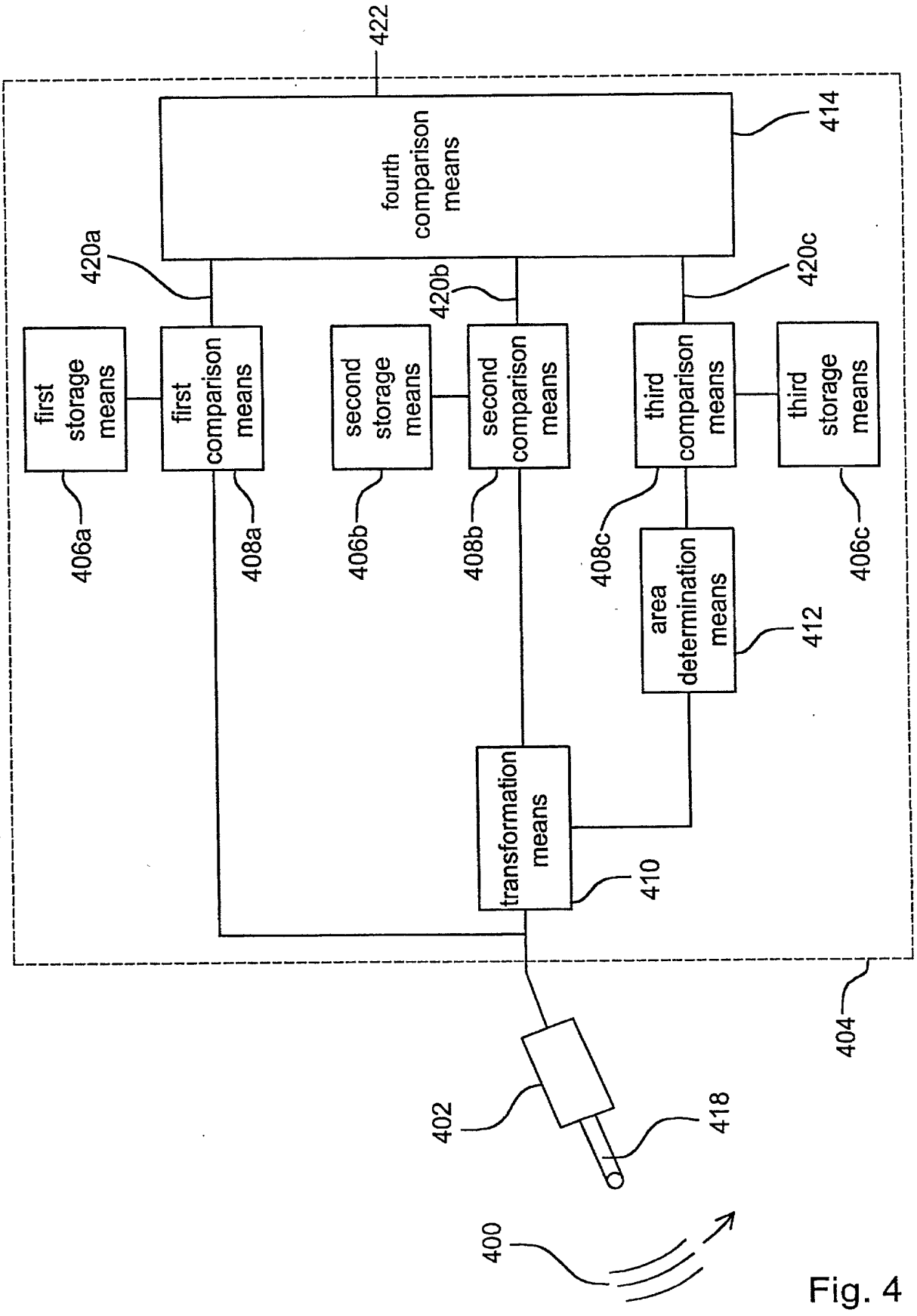
422
fourth comparison means
414
420a
420b
420c
first storage means
first comparison means
second storage means
second comparison means
third comparison means
third storage means
406a
408a
406b
408b
408c
406c
area determination means
412
transformation means
410
404
402
418
400

Fig. 4

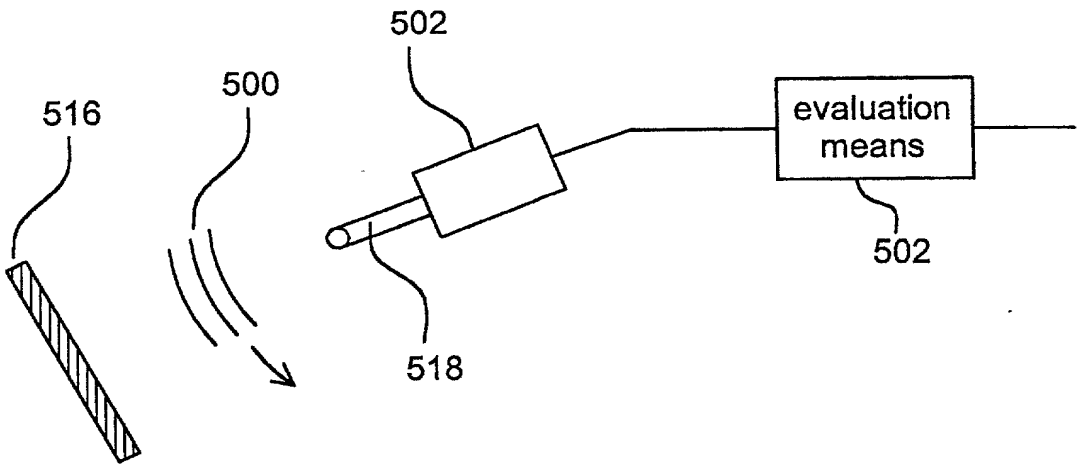

Fig. 5

National Phase of PCT/EP00/04264 in U.S.A.

Title: Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object

Applicant: GRIEBEL, Marion

Annotated copy of Final version of PCT/EP00/04264

Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object

~~Description~~

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates in general to a device for determining the thickness or the number of sheets of a moving sheet-like object, and in particular to a device for determining the number of sheets in a stack of paper.

Description of Prior Art

Conventional devices for determining the thickness or the number of sheets of a sheet-like object are based in essence on two different methods.

On the one hand, there are some devices operating on a mechanical basis. With the aid of a lever operating a microswitch, the edge of the object, e.g. of a stack of sheets, is scanned. This method is in fact of simple construction, but it is unreliable and less suited for moving objects.

In contrast thereto, optoelectronic methods, such as e.g. passing light control, in which the object, e.g. paper, passes through a light barrier, are easier to evaluate. However, they are susceptible of errors as the light transmission changes for different objects, e.g. different kinds of paper or printed images, resulting in misinterpretation of the optical signal.

Both of the afore-mentioned methods of determining the thickness or the number of sheets of a moving sheet-like object,

e.g. a stack of paper, thus entail in part considerable disadvantages concerning the handling, accuracy and reliability in particular with moving sheet-like objects.

Additional methods, such as the distance measurement by inductive and capacitive sensors, do not result in accurate and reliable measurement of the thickness of a sheet-like object either and often are also less suited for measuring the thickness especially of moving sheet-like objects.

DE 3934623 A1 describes a device for folding specimens to be folded, e.g. folding specimens of paper, using an adjustable folding pressure, in particular for simultaneously measuring the thickness and the compressibility of the folding specimens. The thickness of folding specimens of paper can be determined by way of the folding pressure.

DE 3612914 A1 discloses a device for measuring the thickness of paper or the like, in which the paper rests on a support, and a movably supported sensor is provided which is responsive to the position of the surface of the paper and which is carried by an air cushion; the position of said sensor and thus the thickness of the paper can be determined by a measurement device.

DE 3922992 C2 discloses a means for recognizing both the thickness and the edges of recording media in processing apparatus, in particular in printers, in which the recording media rest on a support with an as small gap as possible and are adapted to be scanned by a sensing element measuring the lift and performing a relative movement with respect to the recording medium, with measured lift differences being converted to electrical signals representing the thickness of the recording media.

EP 0635696 B1 describes a device for the electronic measurement of the thickness of thin webs or sheets, in particular

foils, films or paper sheets, consisting of a fixed supporting surface and a tactile sensor arranged in fixed manner and substantially perpendicularly to this supporting surface and having a ferromagnetic tactile member which is movable relative to the supporting surface and, as a function of its position relative to the supporting surface, influences the signal of an inductive transducer in the form of a sensor coil and thus indicates the thickness of the webs or sheets.

DE 19537340 A1 describes a page sensor apparatus for producing a signal related to a thickness of a sheet of paper, which comprises a base plate and a foot plate positioned in opposed relation. The base and foot plates are arranged to allow the paper to pass therebetween, so that the base and foot plates are separated by a distance substantially equal to the thickness of the sheet of paper. A capacitance sensing means connected to the base plate and the foot plate senses changes in the electrical capacitance of the base and foot plates and generates an output signal related to the plate separation and thus the paper thickness.

EP 0442727 A2 discloses a paper thickness detecting apparatus comprising an electrode detecting unit constituted by a ground electrode and an opposing detecting electrode arranged in upper and lower positions of a running path of paper, an oscillating circuit for generating an oscillation frequency signal, a resonant circuit for shifting a resonant point in response to a change in electrostatic capacitance corresponding to a change in paper thickness detected by the electrode detecting unit, and a detecting circuit for detecting an output signal of said resonant circuit in order to determine the thickness of the paper.

US 5,012,248 describes a device for determining the thickness of radar absorption material coatings. The device comprises a radiating element assembly for transmitting RF energy and recovering reflected RF energy from the coating. A source of a

frequency-modulated RF signal comprises an FM ramp generator assembly, a buffer amplifier assembly and a Gunn oscillator. A ferrite circulator directs the modulated RF signal to the radiating element assembly and the reflected RF energy to a detector assembly. The detector assembly includes a Schottky detector, a video amplifier assembly, a converter/driver assembly and a digital display, and is adapted to sense the reflected RF energy from the coating and provide a visual display in the form of a voltage that is inversely proportional to the amount of the reflected RF energy and is a measure for the thickness of the radar absorption material coating.

US 4,161,731 discloses an FM radar for the measurement of coal thickness wherein an FM transmitter is modulated by the combination of two signals; a horn-type antenna is used, which is filled with a material having a dielectric constant approximating that of coal, the antenna being positioned flush against the coal.

US 5,145,560 discloses a method and a device for determining the liquid jet velocity in a paper making machine. This jet velocity is detected by microwave Doppler-effect velocity sensors. The velocity sensors comprise a means for directing the microwave signal towards a first location of the liquid jet and for receiving the reflected microwave signal from the liquid jet, the velocity sensors including furthermore a means for generating a sensor output signal which is shifted in frequency in accordance with the velocity of the jet at the first location in accordance with the Doppler effect.

DE 3327526 A1 describes a method of determining the wall thickness or acoustic velocity of workpieces by means of an ultrasonic measuring instrument. The ultrasonic measuring instrument comprises two transducer elements accommodated in a common housing, a transmit transducer and a receive transducer that are acoustically isolated from each other and receive and transmit the ultrasonic signals. The transmit ele-

ment is coupled to a transmitter, and the receive element is coupled to a receiver connected to an evaluation unit. On the basis of the travel time of the signal of the transmit transducer reflected from a wall or a workpiece and received in the receive transducer, the evaluation unit determines the workpiece properties, such as the wall thickness or the acoustic velocity of the wall material. The evaluation unit moreover, by means of correction factors, performs corrections on the thickness or travel time measured by the ultrasonic measuring instrument, in accordance with the type of probe used. These correction factors are retrieved by the evaluation unit from a memory (PROM) which furthermore is adapted to store the thickness of a calibration body mounted on the measuring instrument, previously measured thickness values or preset values for measuring a thickness differential. For determining a thickness differential from a previously measured thickness or a predetermined thickness, a comparison means in the form of a comparator may be connected to the evaluation unit. The ultrasonic measuring instrument can also perform thickness measurements during movement relative to an object to be measured, e.g. a wall.

The document WO82/03455 A1 describes a method and a device for measuring layer the thickness of material layers using a frequency-modulated ultrasonic signal. The ultrasonic signal is modulated with a specific, fixed modulation rate and directed to a material layer to be measured. Due to the reflection of the signal on the outer and inner boundary layer of the material, interference of these reflected signals occurs, and the receive signal received by the layer, due to the frequency modulation of the ultrasonic signal transmitted to the layer, thus has a frequency-dependent interference pattern having maxima and minima, which may be used for determining the thickness of the material layer.

DE 3424652 A1 discloses an apparatus for dynamically determining the local weight per unit area of sheet-like material.

The apparatus comprises an arrangement of transmitter, receiver and material to be measured, in which the portions of sound reflected on these elements are faded out of the path of rays between the transmitter and the receiver and at the same time prevents by suitable means, e.g. sound traps, that the faded out portions of sound return to the original path of rays and reach the transmitter and/or receiver. The material to be measured is in the form of sheets and is moved between transmitter and receiver with the aid of guide means, e.g. transport rollers. The sheet-like material to be measured is exposed to sound waves from a sound transmitter, and the portions of sound transmitted and reflected by the material to be measured are measured with the aid of a receiver in order to determine therefrom the weight per unit area.

DE 4141446 C2 describes a method of measuring the thickness of a film of water, snow or ice on a surface, in which a pulse of electromagnetic radiation is directed obliquely from above onto the surface covered with such film. The transition time of the pulse through the film and thus the thickness of the layer are determined by a transition time difference measured in the receiver between a portion of the pulse reflected back to the receiver at the surface of the film and another portion of the pulse reflected back to the receiver at the surface on which said film is located. In a different process, the transition time of a pulse between the transmitter, the surface covered by a film, and the receiver is measured and stored, and this stored transition time is compared with a transition time of a momentarily measured transition time value for a pulse transmitted by the transmitter and reflected at the surface of a film located on the surface and received in the receiver, and the thickness of the film is determined on the basis of this comparison.

A disadvantage of the conventional devices for determining the thickness of and the number of sheets of a sheet-like object resides in that they do not permit accurate and reliable

determination of the thickness and in particular of the number of sheets of a moving sheet-like object, such as a stack of paper.

A further disadvantage of the conventional devices consists in that no non-contacting and at the same time accurate detection of the thickness or of the number of sheets is possible.

Still another disadvantage of the conventional devices consists in that in particular the determination of the thickness or the number of sheets of moving objects, in which e.g. the individual sheets form a loose stack of paper and which are moved on arbitrary guide paths at different velocities, is not possible in accurate and reliable manner.

SUMMARY OF THE INVENTION

It is the object of the present invention to provide a device for determining the thickness or the number of sheets of a ~~moving sheet-like object or of a~~ sheet-like object, which renders possible an accurate, reliable and non-contacting determination of the thickness or the number of sheets of a ~~moving sheet-like object or of a~~ sheet-like object.

This object is met by a device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~according to claim 1 and by a device for determining the thickness or the number of sheets of a sheet-like object according to claim 18~~, comprising:

a transmitting and receiving device for transmitting radiation to the object, for receiving reflected radiation containing at least the part of the radiation transmitted to the object that is reflected by the object, and for generating a signal representing the reflected radiation; and

an evaluator for determining the thickness or number of sheets of the object, which receives the signal representing the reflected radiation, wherein the evaluator comprises:

a memory for storing a plurality of previously determined time signal patterns or a plurality of previously determined frequency spectra or a plurality of previously determined area values of frequency spectra, which are each associated with a specific thickness or number of sheets of the object; and

a comparator for comparing the signal representing the reflected radiation or a frequency spectrum derived therefrom or an area value of a frequency spectrum derived therefrom, to the time signal patterns or frequency spectra or area values of frequency spectra which are stored in the memory and for determining the thickness or the number of sheets of the sheet-like object as a result of the comparison.

The invention, among other things, is based on the finding that the movement of a sheet-like object in accordance with the velocity and the thickness or the number of sheets thereof, respectively, has a different effect, in the instant case also via the Doppler effect, on the characteristics of the reflected portion of radiation directed onto the moving sheet-like object, e.g. microwave radiation, and that thus a determination of the thickness of the moving object or of the number of sheets, respectively, is rendered possible by virtue of predetermined connections between the radiation characteristics and the thickness of the object or the number of sheets.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will be elucidated in more detail hereinafter with reference to the accompanying drawings in which

Fig. 1 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a first preferred embodiment of the present invention;

Fig. 2 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a second preferred embodiment of the present invention;

Fig. 3 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a third preferred embodiment of the present invention;

Fig. 4 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a fourth preferred embodiment of the present invention; and

Fig. 5 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a fifth preferred embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A first preferred embodiment of the present invention will be described in the following with reference to Fig. 1. A device for determining the thickness or the number of sheets of a moving sheet-like object 100 according to the first embodiment of the present invention comprises a transmitting and receiving device 102, such as a microwave sensor having a waveguide antenna 118, or an ultrasonic sensor or an electromagnetic sensor in general or an acoustic sensor. The transmitting and receiving device 102 transmits radiation to the

moving object 100, such as a paper or stack of paper, and receives reflected radiation comprising at least that part of the radiation transmitted to the object that is reflected by the moving sheet-like object 100. In response to receipt of the reflected radiation, the transmitting and receiving device 102 furthermore generates a signal representing this reflected radiation. The device for determining the thickness or the number of sheets of a moving sheet-like object 100 according to the first embodiment of the present invention comprises furthermore an evaluation means 104 determining the thickness of the moving object on the basis of previously determined relationships or connections between signal characteristics and the thickness of the moving object 100.

The radiation emitted by the transmitting and receiving device 102 is scattered by the moving object 100, e.g. sheets of paper, and is reflected back to the transmitting and receiving device 102. The reflected radiation has a shifted frequency with respect to the transmitted radiation due to the Doppler effect. Depending on the type of object, e.g. the type of paper and the thickness of the paper, but also the position and velocity of the moving object, a signal pattern or curve is obtained which, in the time and frequency domain, is characteristic of the paper thickness or the number of sheets of the paper supplied simultaneously in superimposed manner. These signals can be digitized, for example, in the evaluation means 104, supplied to a calculating unit and analyzed there by mathematical auxiliary means.

In the first embodiment of the present invention, the evaluation means 104 comprises a first storage means 106 for storing one or more previously determined time patterns each associated with a specific thickness of the moving object 100. The previously determined time patterns may be determined, for example, empirically by measuring the reflected radiation of a moving object 100 with different thickness or number of sheets, but also e.g. with a different velocity, position

etc.. These characteristic time patterns then are stored in the first storage means 106, e.g. a RAM, of a fixed disc or another storage medium in order to render possible in a practical application later on a comparison with actually measured signal patterns or curves and determine the thickness of object 100 on the basis of this.

In the first embodiment of the present invention, evaluation means 104 comprises furthermore a first comparison means 108 for comparing the time pattern of the signal representing the reflected radiation to the stored, previously determined time patterns and for determining the thickness of the moving object 100 on the basis of the comparisons. This comparison means 108, for example, is capable of retrieving from the first storage means 106 those previously determined characteristic time patterns that are associated with a specific thickness of the moving object in order to compare the same to the actually measured time patterns of the signal representing the reflected radiation. This renders possible a thickness determination by way of the time signal. The first comparison means 108 may be e.g. a fuzzy logic, any other statistical logic, a means carrying out integral value comparisons of integrals of the signals, signal curve comparisons etc.. The first comparison means 108, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A second preferred embodiment of the present invention will be described in the following with reference to Fig. 2. In the second embodiment of the present invention, an evaluation means 204 comprises a transformation means 210 for transforming the time pattern of the signal representing the reflected radiation to the frequency domain, in order to generate a frequency spectrum of the reflected radiation received by a transmitting and receiving device 202. The time pattern can be read, for instance, into a memory, retrieved from the mem-

ory and can be transformed to the frequency domain e.g. by means of transformation means 210, such as a means for performing a Fourier transform, to thus obtain a frequency spectrum. This frequency spectrum again can be stored in a memory for carrying out a comparison later on. However, the frequency spectrum can also be determined directly from the time pattern and then processed further or stored.

In the second embodiment of the present invention, the evaluation means 204 comprises furthermore a second storage means 202, e.g. a RAM, a fixed disc or another storage medium, for storing one or more previously determined frequency spectra each associated with a specific thickness of a moving object 200. These previously determined frequency spectra may be determined, for example, empirically by tests in which the time signals for objects of different thickness, e.g. of stacks of sheets with different numbers of sheets, but also e.g. with a different velocity, position etc. are determined and transformed to the frequency domain. These frequency spectra then are assigned to, or characteristic of, a specific thickness or number of sheets of a moving object 200 having a specific velocity, a specific position etc..

In the second embodiment of the present invention, evaluation means 204 comprises furthermore a second comparison means 208 for comparing the frequency spectrum of the reflected radiation to the stored, previously determined frequency spectrum and for determining the thickness of the moving object 200 on the basis of the comparisons. In doing so, the previously determined frequency spectra, each corresponding to a specific thickness of object 200, are compared to the frequency spectra of signals actually measured by the transmitting and receiving device 202, which correspond to the reflected radiation, in order to thus determine the thickness of object 200. The second comparison means 208 may be e.g. a fuzzy logic, any other statistical logic, a means carrying out integral value comparisons of integrals of the spectra, spectrum pat-

tern comparisons etc.. The second comparison means 208, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A third preferred embodiment of the present invention will be described in the following with reference to Fig. 3. In the third embodiment, an evaluation means 304, in addition to a transformation means 310 identical to the afore-described transformation means 210 of the second embodiment of Fig. 2, comprises a third storage means 306 for storing one or more previously determined area values each associated with a specific thickness of a moving object 300, as well as an area determination means 312 for determining the area of the spectrum delivered by transformation means 310 in the region of a specific frequency, e.g. the Doppler frequency, of the reflected radiation.

During movement of the moving object 300, the part of the radiation reflected by the moving object 300 is shifted in its frequency with respect to the frequency of the transmitted radiation due to the Doppler effect. The frequency transform of the signal or time pattern corresponding to the reflected radiation has a peak value in the region of that frequency that results from the Doppler shift of the transmission frequency of the signal. Around this frequency component, there may be performed an integration or area determination by area determination means 312, since the area in the transform, e.g. the Fourier transform, of the Doppler frequency is a measure for the intensity of the reflection and thus for the question whether, for example, with a sheet-like input or output object of a printer, copier or facsimile device etc., only one sheet or a plurality of sheets have been drawn in or output. The area values can be determined empirically for different configurations of the object, in particular in accordance with the thickness, but in addition also in accordance with the velocity, position, guiding of the object in a

device etc., and can be stored in a memory e.g. in the form of tables, in order to be able later on to determine the thickness of a moving object 300 that is moved with a specific velocity etc., directly by way of comparisons of the actual area values output by the area determination means 312 to the stored characteristic area values.

In the third embodiment of the present invention, evaluation means 304 comprises furthermore a third comparison means 308 for comparing the area determined by the area determination means 312 to the stored, previously determined area values and for determining the thickness of the moving object 300 on the basis of the comparisons. The third comparison means 308 may be e.g. a fuzzy logic or any other statistical logic etc., and, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A fourth preferred embodiment of the present invention will be described in the following with reference to Fig. 4. The device for determining the thickness or the number of sheets of a moving sheet-like object 400 according to the fourth embodiment comprises a transmitting and receiving means 402 and an evaluation means 404 which, as in the third embodiment, comprises a transformation means 410 and an area determination means 412, and in addition first, second and/or third storage means 406a, 406b and 406c, respectively, first, second and/or third comparison means 408a, 408b and 408c, respectively, and optionally a fourth comparison means 414. The first, second and third storage means 406a, 406b and 406c, respectively, correspond to the first, second and third storage means 106, 206, 306 of the first, second and third embodiments of Figs. 1, 2 and 3, and the first, second and third comparison means 408a, 408b and 408c, respectively, correspond to first, second and third comparison means 108, 208, 308 of the first, second and third embodiments of Figs. 1, 2 and 3.

The first, second and third comparison means 408a, 408b and/or 408c may be coupled to comparison means 414, e.g. a fuzzy logic, for examining the conformity of the thickness values determined by the first, second and/or third comparison means 408a, 408b, 408c and for determining a most probable thickness of the moving object 400. This permits still safer determination of the thickness of the moving object 400, e.g. the number of sheets of a stack of paper.

The outputs 120, 220, 320, 420a, 420b, 420c, 422 of the comparison means 108, 208, 308, 408a, 408b, 408c, 414 of the first, second, third and fourth embodiments may be, for example, binary signals having a specific bit width, which code the thickness or the number of sheets of the moving sheet-like object or provide information as to which most probable thickness or number of sheets the moving object, e.g. a stack of paper consisting of sheets, has.

In a fifth preferred embodiment of the present invention, the device for determining the thickness or the number of sheets of a moving sheet-like object 500 comprises furthermore a reflector 516 which, with respect to a transmitting and receiving device 502 is arranged behind the moving object 500 and which reflects the radiation transmitted through the moving object 500 to the moving object 500 and to the transmitting and receiving device 502. This reflector 516 has the effect that the radiation reflected to the transmitting and receiving device 502 contains the radiation reflected by reflector 516 in addition to the radiation reflected by the moving object 500. This yields a mixed signal which, similar to the statements made hereinbefore, can be processed by an evaluation means 504 and analyzed to determine the thickness of the moving object 500.

By means of the device for determining the thickness and the number of sheets of a sheet-like object according to any of

the preceding embodiments it is possible furthermore to measure the thickness or the number of sheets of a non-moving object.

In a first embodiment this is possible by moving the device or the transmitting and receiving device, respectively. In doing so, for example the transmitting and receiving device is moved on a platform preferably over small distances, e.g. in an oscillating motion, towards the object and away from the object. This movement can be generated, for example, by an oscillation generating member, e.g. a piezoelectric member, mechanical oscillation generating members etc.. However, it is also possible to vary the focusing or the form of the radiation used in order to simulate this movement. This can be effected e.g. by means of lenses, diaphragms etc.. Moreover, mirror elements or deflection means altering the beam travel length, such as mirrors arranged in the direction of the beam, may be utilized to alter the travel lengths of the radiation and thus simulate a movement.

In a second embodiment, there is, for example, neither a movement of the transmitting and receiving device nor of the object, and only the signal form received by the object, e.g. the time signal of the reflected radiation, is detected. This reflected signal, in terms of its width and form, is dependent upon the number of layers or sheets of the sheet-like object, since the signal portions reflected on these layers have different travel-back times to the receiving device and thus broaden the reflected signal e.g. in terms of time. On the basis of the width, it is then possible to determine the number of sheets or the thickness of the object. The reflected signal can be processed in various ways, as elucidated hereinbefore in connection with the previous embodiments, and can be compared to stored experimental values for reflected signals associated with different object thickness values. By statistical evaluation of the signal form received and of signal forms, stored or determined or learned during

operation, which are associated with different thickness values, the thickness of an object can be determined simply and rapidly.

The device for determining the thickness or the number of sheets of a moving sheet-like object or of a sheet-like object according to the present invention renders possible facilitated handling without operational elements. Software analysis of the characteristic signals, spectra, areas permits e.g. arbitrary accuracy, thereby increasing reliability to a high degree as well. The device of the present invention furthermore renders possible a simple construction, improved evaluation possibilities, is based on a non-contacting process and is flexibly applicable to various configurations, e.g. in paper manufacture, paper processing and paper handling. It may be employed e.g. in the utilization of microwave radiation with all sheet-like objects having a thickness between 1/10 mm and some millimeters.

~~Claims~~

What is claimed is:

1. A device for determining the thickness or the number of sheets of a sheet-like object ~~(100; 200; 300; 400; 500)~~, comprising:

- a transmitting and receiving device ~~(102; 202; 302; 402; 502)~~ for transmitting radiation to the ~~moving~~ object ~~(100; 200; 300; 400; 500)~~, for receiving reflected radiation containing at least the part of the radiation transmitted to the object ~~(100; 200; 300; 400; 500)~~ that is reflected by the ~~moving~~ object ~~(100; 200; 300; 400; 500)~~, and for generating a signal representing the reflected radiation; and

- an evaluator ~~evaluation means (104; 204; 304; 404; 504)~~ for determining the thickness or number of sheets of the ~~moving~~ object ~~(100; 200; 300; 400; 500)~~, which receives the signal representing the reflected radiation,

~~characterized in~~

~~that~~ wherein the evaluator ~~evaluation means (104; 204; 304; 404; 504) receives the signal representing the reflected radiation, compares a signal pattern of the signal representing the reflected radiation to stored signal patterns for predetermined thickness values of the moving object (104; 204; 304; 404; 504) and determines the thickness of the moving object (104; 204; 304; 404; 504) as a function of said comparison~~ comprises:

- a memory for storing a plurality of previously determined time signal patterns or a plurality of previously determined frequency spectra or a plurality of previously determined area values of frequency

spectra, which are each associated with a specific thickness or number of sheets of the object; and

- a comparator for comparing the signal representing the reflected radiation or a frequency spectrum derived therefrom or an area value of a frequency spectrum derived therefrom, to the time signal patterns or frequency spectra or area values of frequency spectra which are stored in the memory and for determining the thickness or the number of sheets of the sheet-like object as a result of the comparison.

2. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 400)~~ according to claim 1, wherein ~~the evaluation means (104; 404) further comprises:~~

the memory comprises a first memory ~~storage means (106; 406a)~~ for storing one or more previously determined time signal patterns each associated with a specific thickness of the object ~~(100; 400)~~; and

~~a first comparison means (108; 408a)~~the comparator comprises a first comparator for comparing the time signal pattern of the signal representing the reflected radiation to the stored previously determined time signal patterns and for determining the thickness of the object ~~(100; 400)~~ on the basis of the comparisons.

3. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(200; 300; 400)~~ according to claim 1 ~~or 2~~, wherein the ~~evaluation means (204; 304; 404)~~ evaluator further comprises:

a ~~transformation means (210; 310; 410)~~ transformator for transforming the time signal pattern of the signal rep-

resenting the reflected radiation to the frequency domain in order to generate a frequency spectrum of the reflected radiation.

4. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(200; 300; 400)~~ according to claim 3, wherein the ~~transformation means (210; 310; 410)~~ transformator carries out a Fourier transform.

5. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(200; 400)~~ according to claim 3 ~~or 4~~, wherein the ~~evaluation means (204; 404)~~ evaluator comprises furthermore:

a ~~second storage means (206; 406b)~~ frequency spectra memory for storing ~~one or more~~ a plurality previously determined frequency spectra each associated with a specific thickness of the ~~moving~~ object ~~(200; 400)~~; and

a second ~~comparison means (208; 408b)~~ comparator for comparing the frequency spectrum of the reflected radiation to the stored previously determined frequency spectra and for determining the thickness of the ~~moving~~ object ~~(200; 400)~~ on the basis of the comparisons.

6. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(300; 400)~~ according to ~~any of~~ claim~~s~~ 3 ~~to 5~~, wherein the ~~evaluation means (304; 404)~~ evaluator comprises furthermore:

an ~~third storage means (206; 406b)~~ area value memory for storing ~~one or more~~ a plurality of previously determined area values each associated with a specific thickness of the ~~moving~~ object ~~(300; 400)~~;

an area ~~determination means (312; 412)~~ determinator for determining the area of the spectrum around the frequency corresponding to the Doppler shift of the frequency of the radiation transmitted to the ~~moving~~ object ~~(300; 400)~~; and

a third ~~comparison means (308; 408c)~~ comparator for comparing the area determined to the stored, previously determined area values and for determining the thickness of the ~~moving~~ object ~~(100)~~ on the basis of the comparisons.

7. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(500)~~ according to ~~any of the preceding~~ claim~~s~~ 1, comprising furthermore a reflector ~~(516)~~ which, with respect to the transmitting and receiving device ~~(502)~~, is disposed behind the ~~moving~~ object ~~(500)~~ and which reflects the radiation transmitted through the ~~moving~~ object ~~(500)~~ to the ~~moving~~ object ~~(500)~~ and to the transmitting and receiving device ~~(502)~~.

8. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 200; 300; 400)~~ according to ~~any of the preceding~~ claim~~s~~ 1, wherein the ~~first, second and/or third comparison means (108; 208; 308; 408a, b, c)~~ comparators comprise a fuzzy logic.

9. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(400)~~ according to ~~any of the preceding~~ claim~~s~~ 1, wherein the ~~first, second and/or third comparison means (408a, b, c)~~ comparators are coupled to a fourth ~~comparison means (414)~~ comparator for examining the conformity of the thicknesses determined by the ~~comparison means (408a, b, c)~~ compara-

tors and for determining a most probable thickness of the object ~~(400)~~.

10. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(400)~~ according to claim 9, wherein the fourth ~~comparison means (414)~~ comparator is a fuzzy logic.

11. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 200; 300; 400; 500)~~ according to ~~any of the preceding~~ claim~~s~~ 1, wherein the radiation is electromagnetic or acoustic radiation.

12. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 200; 300; 400; 500)~~ according to claim 11, wherein the radiation is microwave radiation.

13. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 200; 300; 400; 500)~~ according to claim 11 ~~or 12~~, wherein the transmitting and receiving device ~~(102; 202; 302; 402; 502)~~ comprises a waveguide antenna ~~(118; 218; 318; 418; 518)~~.

14. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 200; 300; 400; 500)~~ according to claim 11, wherein the radiation is ultrasonic radiation.

15. A device for determining the thickness or the number of sheets of a ~~moving~~ sheet-like object ~~(100; 200, 300; 400; 500)~~ according to ~~any of the preceding~~ claim~~s~~ 1, wherein the ~~moving~~ object ~~(100; 200; 300; 400; 500)~~ is a moving stack of sheets and the thickness of the moving stack of sheets is a measure for the number of media.

16. A device for determining the thickness or the number of sheets of a moving sheet-like object ~~(100; 200; 300; 400; 500)~~ according to claim 15, wherein the moving stack of sheets is a stack of paper.

17. A device for determining the thickness or the number of sheets of a sheet-like object ~~(100; 200; 300; 400; 500)~~ according to ~~any of the preceding~~ claim~~s~~ 15, wherein the transmitting and receiving device ~~(102; 202; 302; 402; 502)~~ is in motion instead of the object.

~~18. A device for determining the thickness or the number of sheets of a sheet-like object (100; 200; 300; 400; 500), comprising~~

~~a transmitting and receiving device (102; 202; 302; 402; 502) for transmitting radiation to the object (100; 200; 300; 400; 500), for receiving reflected radiation containing at least the part of the radiation transmitted to the object (100; 200; 300; 400; 500) that is reflected by the object (100; 200; 300; 400; 500), and for generating a signal representing the reflected radiation; and~~

~~an evaluation means (104; 204; 304; 404; 504) for determining the thickness of the object (100; 200; 300; 400; 500),~~

~~characterized in~~

~~that the evaluation means (104; 204; 304; 404; 504) receives the signal representing the reflected radiation, compares a signal pattern of the signal representing the reflected radiation to stored signal patterns for predetermined thickness values of the object (104; 204; 304; 404; 504) and determines the thickness of the object~~

~~(104; 204; 304; 404; 504) as a function of said comparison.~~

~~19. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 400) according to claim 18, wherein the evaluation means (104; 404) further comprises:~~

~~a first storage means (106; 406a) for storing one or more previously determined time signal patterns each associated with a specific thickness of the object (100; 400); and~~

~~a first comparison means (108; 408a) for comparing the time signal pattern of the signal representing the reflected radiation to the stored previously determined time signal patterns and for determining the thickness of the object (100; 400) on the basis of the comparisons.~~

~~20. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 300; 400) according to claim 18 or 19, wherein the evaluation means (204; 304; 404) further comprises:~~

~~a transformation means (210; 310; 410) for transforming the time signal pattern of the signal representing the reflected radiation to the frequency domain in order to generate a frequency spectrum of the reflected radiation.~~

~~21. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 400) according to claim 20, wherein the evaluation means (204; 404) comprises furthermore:~~

~~a second storage means (206; 406b) for storing one or more previously determined frequency spectra each associated with a specific thickness of the object (200; 400); and~~

~~a second comparison means (208; 408b) for comparing the frequency spectrum of the reflected radiation to the stored previously determined frequency spectra and for determining the thickness of the object (200; 400) on the basis of the comparisons.~~

~~22. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400) according to any of the preceding claims, wherein the first and second comparison means (108; 208; 408a, b) comprise a fuzzy logic.~~

~~Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object~~

ABSTRACT

A device for determining the thickness or the number of sheets of a sheet-like object ~~(100), comprising~~ has a transmitting and receiving device ~~(102)~~ for transmitting radiation to the object, for receiving reflected radiation containing at least the part of the radiation transmitted to the object ~~(100)~~ that is reflected by the object ~~(100)~~, and for generating a signal representing the reflected radiation. An evaluator is provided~~, and an evaluation means (104)~~ for determining the thickness or number of sheets of the object ~~(100) on the basis of previously determined connections between the signal characteristics and the thickness of the object (100)~~, which receives the signal representing the reflected radiation. The evaluator has a memory for storing a plurality of previously determined time signal patterns or a plurality of previously determined frequency spectra or a plurality of previously determined area values of frequency spectra, which are each associated with a specific thickness or number of sheets of the object, and a comparator for comparing the signal representing the reflected radiation or a frequency spectrum derived therefrom or an area value of a frequency spectrum derived therefrom, to the time signal patterns or frequency spectra or area values of frequency spectra which are stored in the memory and for determining the thickness or the number of sheets of the sheet-like object as a result of the comparison.

National Phase of PCT/EP00/04264 in U.S.A.

Title: Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object

Applicant: GRIEBEL, Marion

Translation of PCT Application PCT/EP00/04264
as originally filed

Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object

Description

The present invention relates in general to a device for determining the thickness or the number of sheets of a moving sheet-like object, and in particular to a device for determining the number of sheets in a stack of paper.

Conventional devices for determining the thickness or the number of sheets of a sheet-like object are based in essence on two different methods.

On the one hand, there are some devices operating on a mechanical basis. With the aid of a lever operating a microswitch, the edge of the object, e.g. of a stack of sheets, is scanned. This method is in fact of simple construction, but it is unreliable and less suited for moving objects.

In contrast thereto, optoelectronic methods, such as e.g. passing light control, in which the object, e.g. paper, passes through a light barrier, are easier to evaluate. However, they are susceptible of errors as the light transmission changes for different objects, e.g. different kinds of paper or printed images, resulting in misinterpretation of the optical signal.

Both of the afore-mentioned methods of determining the thickness or the number of sheets of a moving sheet-like object, e.g. a stack of paper, thus entail in part considerable disadvantages concerning the handling, accuracy and reliability in particular with moving sheet-like objects.

Additional methods, such as the distance measurement by inductive and capacitive sensors, do not result in accurate and

reliable measurement of the thickness of a sheet-like object either and often are also less suited for measuring the thickness especially of moving sheet-like objects.

DE 3934623 A1 describes a device for folding specimens to be folded, e.g. folding specimens of paper, using an adjustable folding pressure, in particular for simultaneously measuring the thickness and the compressibility of the folding specimens. The thickness of folding specimens of paper can be determined by way of the folding pressure.

DE 3612914 A1 discloses a device for measuring the thickness of paper or the like, in which the paper rests on a support, and a movably supported sensor is provided which is responsive to the position of the surface of the paper and which is carried by an air cushion; the position of said sensor and thus the thickness of the paper can be determined by a measurement device.

DE 3922992 C2 discloses a means for recognizing both the thickness and the edges of recording media in processing apparatus, in particular in printers, in which the recording media rest on a support with an as small gap as possible and are adapted to be scanned by a sensing element measuring the lift and performing a relative movement with respect to the recording medium, with measured lift differences being converted to electrical signals representing the thickness of the recording media.

EP 0635696 B1 describes a device for the electronic measurement of the thickness of thin webs or sheets, in particular foils, films or paper sheets, consisting of a fixed supporting surface and a tactile sensor arranged in fixed manner and substantially perpendicularly to this supporting surface and having a ferromagnetic tactile member which is movable relative to the supporting surface and, as a function of its position relative to the supporting surface, influences the

signal of an inductive transducer in the form of a sensor coil and thus indicates the thickness of the webs or sheets.

DE 19537340 A1 describes a page sensor apparatus for producing a signal related to a thickness of a sheet of paper, which comprises a base plate and a foot plate positioned in opposed relation. The base and foot plates are arranged to allow the paper to pass therebetween, so that the base and foot plates are separated by a distance substantially equal to the thickness of the sheet of paper. A capacitance sensing means connected to the base plate and the foot plate senses changes in the electrical capacitance of the base and foot plates and generates an output signal related to the plate separation and thus the paper thickness.

EP 0442727 A2 discloses a paper thickness detecting apparatus comprising an electrode detecting unit constituted by a ground electrode and an opposing detecting electrode arranged in upper and lower positions of a running path of paper, an oscillating circuit for generating an oscillation frequency signal, a resonant circuit for shifting a resonant point in response to a change in electrostatic capacitance corresponding to a change in paper thickness detected by the electrode detecting unit, and a detecting circuit for detecting an output signal of said resonant circuit in order to determine the thickness of the paper.

US 5,012,248 describes a device for determining the thickness of radar absorption material coatings. The device comprises a radiating element assembly for transmitting RF energy and recovering reflected RF energy from the coating. A source of a frequency-modulated RF signal comprises an FM ramp generator assembly, a buffer amplifier assembly and a Gunn oscillator. A ferrite circulator directs the modulated RF signal to the radiating element assembly and the reflected RF energy to a detector assembly. The detector assembly includes a Schottky detector, a video amplifier assembly, a converter/driver as-

sembly and a digital display, and is adapted to sense the reflected RF energy from the coating and provide a visual display in the form of a voltage that is inversely proportional to the amount of the reflected RF energy and is a measure for the thickness of the radar absorption material coating.

US 4,161,731 discloses an FM radar for the measurement of coal thickness wherein an FM transmitter is modulated by the combination of two signals; a horn-type antenna is used, which is filled with a material having a dielectric constant approximating that of coal, the antenna being positioned flush against the coal.

US 5,145,560 discloses a method and a device for determining the liquid jet velocity in a paper making machine. This jet velocity is detected by microwave Doppler-effect velocity sensors. The velocity sensors comprise a means for directing the microwave signal towards a first location of the liquid jet and for receiving the reflected microwave signal from the liquid jet, the velocity sensors including furthermore a means for generating a sensor output signal which is shifted in frequency in accordance with the velocity of the jet at the first location in accordance with the Doppler effect.

DE 3327526 A1 describes a method of determining the wall thickness or acoustic velocity of workpieces by means of an ultrasonic measuring instrument. The ultrasonic measuring instrument comprises two transducer elements accommodated in a common housing, a transmit transducer and a receive transducer that are acoustically isolated from each other and receive and transmit the ultrasonic signals. The transmit element is coupled to a transmitter, and the receive element is coupled to a receiver connected to an evaluation unit. On the basis of the travel time of the signal of the transmit transducer reflected from a wall or a workpiece and received in the receive transducer, the evaluation unit determines the workpiece properties, such as the wall thickness or the

acoustic velocity of the wall material. The evaluation unit moreover, by means of correction factors, performs corrections on the thickness or travel time measured by the ultrasonic measuring instrument, in accordance with the type of probe used. These correction factors are retrieved by the evaluation unit from a memory (PROM) which furthermore is adapted to store the thickness of a calibration body mounted on the measuring instrument, previously measured thickness values or preset values for measuring a thickness differential. For determining a thickness differential from a previously measured thickness or a predetermined thickness, a comparison means in the form of a comparator may be connected to the evaluation unit. The ultrasonic measuring instrument can also perform thickness measurements during movement relative to an object to be measured, e.g. a wall.

The document WO82/03455 A1 describes a method and a device for measuring layer the thickness of material layers using a frequency-modulated ultrasonic signal. The ultrasonic signal is modulated with a specific, fixed modulation rate and directed to a material layer to be measured. Due to the reflection of the signal on the outer and inner boundary layer of the material, interference of these reflected signals occurs, and the receive signal received by the layer, due to the frequency modulation of the ultrasonic signal transmitted to the layer, thus has a frequency-dependent interference pattern having maxima and minima, which may be used for determining the thickness of the material layer.

DE 3424652 A1 discloses an apparatus for dynamically determining the local weight per unit area of sheet-like material. The apparatus comprises an arrangement of transmitter, receiver and material to be measured, in which the portions of sound reflected on these elements are faded out of the path of rays between the transmitter and the receiver and at the same time prevents by suitable means, e.g. sound traps, that the faded out portions of sound return to the original path

of rays and reach the transmitter and/or receiver. The material to be measured is in the form of sheets and is moved between transmitter and receiver with the aid of guide means, e.g. transport rollers. The sheet-like material to be measured is exposed to sound waves from a sound transmitter, and the portions of sound transmitted and reflected by the material to be measured are measured with the aid of a receiver in order to determine therefrom the weight per unit area.

DE 4141446 C2 describes a method of measuring the thickness of a film of water, snow or ice on a surface, in which a pulse of electromagnetic radiation is directed obliquely from above onto the surface covered with such film. The transition time of the pulse through the film and thus the thickness of the layer are determined by a transition time difference measured in the receiver between a portion of the pulse reflected back to the receiver at the surface of the film and another portion of the pulse reflected back to the receiver at the surface on which said film is located. In a different process, the transition time of a pulse between the transmitter, the surface covered by a film, and the receiver is measured and stored, and this stored transition time is compared with a transition time of a momentarily measured transition time value for a pulse transmitted by the transmitter and reflected at the surface of a film located on the surface and received in the receiver, and the thickness of the film is determined on the basis of this comparison.

A disadvantage of the conventional devices for determining the thickness of and the number of sheets of a sheet-like object resides in that they do not permit accurate and reliable determination of the thickness and in particular of the number of sheets of a moving sheet-like object, such as a stack of paper.

A further disadvantage of the conventional devices consists in that no non-contacting and at the same time accurate de-

tection of the thickness or of the number of sheets is possible.

Still another disadvantage of the conventional devices consists in that in particular the determination of the thickness or the number of sheets of moving objects, in which e.g. the individual sheets form a loose stack of paper and which are moved on arbitrary guide paths at different velocities, is not possible in accurate and reliable manner.

It is the object of the present invention to provide a device for determining the thickness or the number of sheets of a moving sheet-like object or of a sheet-like object, which renders possible an accurate, reliable and non-contacting determination of the thickness or the number of sheets of a moving sheet-like object or of a sheet-like object.

This object is met by a device for determining the thickness or the number of sheets of a moving sheet-like object according to claim 1 and by a device for determining the thickness or the number of sheets of a sheet-like object according to claim 18.

The invention, among other things, is based on the finding that the movement of a sheet-like object in accordance with the velocity and the thickness or the number of sheets thereof, respectively, has a different effect, in the instant case also via the Doppler effect, on the characteristics of the reflected portion of radiation directed onto the moving sheet-like object, e.g. microwave radiation, and that thus a determination of the thickness of the moving object or of the number of sheets, respectively, is rendered possible by virtue of predetermined connections between the radiation characteristics and the thickness of the object or the number of sheets.

Preferred embodiments of the present invention will be elucidated in more detail hereinafter with reference to the accompanying drawings in which

Fig. 1 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a first preferred embodiment of the present invention;

Fig. 2 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a second preferred embodiment of the present invention;

Fig. 3 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a third preferred embodiment of the present invention;

Fig. 4 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a fourth preferred embodiment of the present invention; and

Fig. 5 shows a device for determining the thickness or the number of sheets of a moving sheet-like object according to a fifth preferred embodiment of the present invention.

A first preferred embodiment of the present invention will be described in the following with reference to Fig. 1. A device for determining the thickness or the number of sheets of a moving sheet-like object 100 according to the first embodiment of the present invention comprises a transmitting and receiving device 102, such as a microwave sensor having a waveguide antenna 118, or an ultrasonic sensor or an electromagnetic sensor in general or an acoustic sensor. The trans-

mitting and receiving device 102 transmits radiation to the moving object 100, such as a paper or stack of paper, and receives reflected radiation comprising at least that part of the radiation transmitted to the object that is reflected by the moving sheet-like object 100. In response to receipt of the reflected radiation, the transmitting and receiving device 102 furthermore generates a signal representing this reflected radiation. The device for determining the thickness or the number of sheets of a moving sheet-like object 100 according to the first embodiment of the present invention comprises furthermore an evaluation means 104 determining the thickness of the moving object on the basis of previously determined relationships or connections between signal characteristics and the thickness of the moving object 100.

The radiation emitted by the transmitting and receiving device 102 is scattered by the moving object 100, e.g. sheets of paper, and is reflected back to the transmitting and receiving device 102. The reflected radiation has a shifted frequency with respect to the transmitted radiation due to the Doppler effect. Depending on the type of object, e.g. the type of paper and the thickness of the paper, but also the position and velocity of the moving object, a signal pattern or curve is obtained which, in the time and frequency domain, is characteristic of the paper thickness or the number of sheets of the paper supplied simultaneously in superimposed manner. These signals can be digitized, for example, in the evaluation means 104, supplied to a calculating unit and analyzed there by mathematical auxiliary means.

In the first embodiment of the present invention, the evaluation means 104 comprises a first storage means 106 for storing one or more previously determined time patterns each associated with a specific thickness of the moving object 100. The previously determined time patterns may be determined, for example, empirically by measuring the reflected radiation of a moving object 100 with different thickness or number of

sheets, but also e.g. with a different velocity, position etc.. These characteristic time patterns then are stored in the first storage means 106, e.g. a RAM, of a fixed disc or another storage medium in order to render possible in a practical application later on a comparison with actually measured signal patterns or curves and determine the thickness of object 100 on the basis of this.

In the first embodiment of the present invention, evaluation means 104 comprises furthermore a first comparison means 108 for comparing the time pattern of the signal representing the reflected radiation to the stored, previously determined time patterns and for determining the thickness of the moving object 100 on the basis of the comparisons. This comparison means 108, for example, is capable of retrieving from the first storage means 106 those previously determined characteristic time patterns that are associated with a specific thickness of the moving object in order to compare the same to the actually measured time patterns of the signal representing the reflected radiation. This renders possible a thickness determination by way of the time signal. The first comparison means 108 may be e.g. a fuzzy logic, any other statistical logic, a means carrying out integral value comparisons of integrals of the signals, signal curve comparisons etc.. The first comparison means 108, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A second preferred embodiment of the present invention will be described in the following with reference to Fig. 2. In the second embodiment of the present invention, an evaluation means 204 comprises a transformation means 210 for transforming the time pattern of the signal representing the reflected radiation to the frequency domain, in order to generate a frequency spectrum of the reflected radiation received by a transmitting and receiving device 202. The time pattern can

be read, for instance, into a memory, retrieved from the memory and can be transformed to the frequency domain e.g. by means of transformation means 210, such as a means for performing a Fourier transform, to thus obtain a frequency spectrum. This frequency spectrum again can be stored in a memory for carrying out a comparison later on. However, the frequency spectrum can also be determined directly from the time pattern and then processed further or stored.

In the second embodiment of the present invention, the evaluation means 204 comprises furthermore a second storage means 202, e.g. a RAM, a fixed disc or another storage medium, for storing one or more previously determined frequency spectra each associated with a specific thickness of a moving object 200. These previously determined frequency spectra may be determined, for example, empirically by tests in which the time signals for objects of different thickness, e.g. of stacks of sheets with different numbers of sheets, but also e.g. with a different velocity, position etc. are determined and transformed to the frequency domain. These frequency spectra then are assigned to, or characteristic of, a specific thickness or number of sheets of a moving object 200 having a specific velocity, a specific position etc..

In the second embodiment of the present invention, evaluation means 204 comprises furthermore a second comparison means 208 for comparing the frequency spectrum of the reflected radiation to the stored, previously determined frequency spectrum and for determining the thickness of the moving object 200 on the basis of the comparisons. In doing so, the previously determined frequency spectra, each corresponding to a specific thickness of object 200, are compared to the frequency spectra of signals actually measured by the transmitting and receiving device 202, which correspond to the reflected radiation, in order to thus determine the thickness of object 200. The second comparison means 208 may be e.g. a fuzzy logic, any other statistical logic, a means carrying out integral

value comparisons of integrals of the spectra, spectrum pattern comparisons etc.. The second comparison means 208, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A third preferred embodiment of the present invention will be described in the following with reference to Fig. 3. In the third embodiment, an evaluation means 304, in addition to a transformation means 310 identical to the afore-described transformation means 210 of the second embodiment of Fig. 2, comprises a third storage means 306 for storing one or more previously determined area values each associated with a specific thickness of a moving object 300, as well as an area determination means 312 for determining the area of the spectrum delivered by transformation means 310 in the region of a specific frequency, e.g. the Doppler frequency, of the reflected radiation.

During movement of the moving object 300, the part of the radiation reflected by the moving object 300 is shifted in its frequency with respect to the frequency of the transmitted radiation due to the Doppler effect. The frequency transform of the signal or time pattern corresponding to the reflected radiation has a peak value in the region of that frequency that results from the Doppler shift of the transmission frequency of the signal. Around this frequency component, there may be performed an integration or area determination by area determination means 312, since the area in the transform, e.g. the Fourier transform, of the Doppler frequency is a measure for the intensity of the reflection and thus for the question whether, for example, with a sheet-like input or output object of a printer, copier or facsimile device etc., only one sheet or a plurality of sheets have been drawn in or output. The area values can be determined empirically for different configurations of the object, in particular in accordance with the thickness, but in addition also in accor-

dance with the velocity, position, guiding of the object in a device etc., and can be stored in a memory e.g. in the form of tables, in order to be able later on to determine the thickness of a moving object 300 that is moved with a specific velocity etc., directly by way of comparisons of the actual area values output by the area determination means 312 to the stored characteristic area values.

In the third embodiment of the present invention, evaluation means 304 comprises furthermore a third comparison means 308 for comparing the area determined by the area determination means 312 to the stored, previously determined area values and for determining the thickness of the moving object 300 on the basis of the comparisons. The third comparison means 308 may be e.g. a fuzzy logic or any other statistical logic etc., and, both in terms of hardware and in terms of software, may be implemented with arbitrary accuracy of the comparison, e.g. number of the binary positions.

A fourth preferred embodiment of the present invention will be described in the following with reference to Fig. 4. The device for determining the thickness or the number of sheets of a moving sheet-like object 400 according to the fourth embodiment comprises a transmitting and receiving means 402 and an evaluation means 404 which, as in the third embodiment, comprises a transformation means 410 and an area determination means 412, and in addition first, second and/or third storage means 406a, 406b and 406c, respectively, first, second and/or third comparison means 408a, 408b and 408c, respectively, and optionally a fourth comparison means 414. The first, second and third storage means 406a, 406b and 406c, respectively, correspond to the first, second and third storage means 106, 206, 306 of the first, second and third embodiments of Figs. 1, 2 and 3, and the first, second and third comparison means 408a, 408b and 408c, respectively, correspond to first, second and third comparison means 108,

208, 308 of the first, second and third embodiments of Figs. 1, 2 and 3.

The first, second and third comparison means 408a, 408b and/or 408c may be coupled to comparison means 414, e.g. a fuzzy logic, for examining the conformity of the thickness values determined by the first, second and/or third comparison means 408a, 408b, 408c and for determining a most probable thickness of the moving object 400. This permits still safer determination of the thickness of the moving object 400, e.g. the number of sheets of a stack of paper.

The outputs 120, 220, 320, 420a, 420b, 420c, 422 of the comparison means 108, 208, 308, 408a, 408b, 408c, 414 of the first, second, third and fourth embodiments may be, for example, binary signals having a specific bit width, which code the thickness or the number of sheets of the moving sheet-like object or provide information as to which most probable thickness or number of sheets the moving object, e.g. a stack of paper consisting of sheets, has.

In a fifth preferred embodiment of the present invention, the device for determining the thickness or the number of sheets of a moving sheet-like object 500 comprises furthermore a reflector 516 which, with respect to a transmitting and receiving device 502 is arranged behind the moving object 500 and which reflects the radiation transmitted through the moving object 500 to the moving object 500 and to the transmitting and receiving device 502. This reflector 516 has the effect that the radiation reflected to the transmitting and receiving device 502 contains the radiation reflected by reflector 516 in addition to the radiation reflected by the moving object 500. This yields a mixed signal which, similar to the statements made hereinbefore, can be processed by an evaluation means 504 and analyzed to determine the thickness of the moving object 500.

By means of the device for determining the thickness and the number of sheets of a sheet-like object according to any of the preceding embodiments it is possible furthermore to measure the thickness or the number of sheets of a non-moving object.

In a first embodiment this is possible by moving the device or the transmitting and receiving device, respectively. In doing so, for example the transmitting and receiving device is moved on a platform preferably over small distances, e.g. in an oscillating motion, towards the object and away from the object. This movement can be generated, for example, by an oscillation generating member, e.g. a piezoelectric member, mechanical oscillation generating members etc.. However, it is also possible to vary the focusing or the form of the radiation used in order to simulate this movement. This can be effected e.g. by means of lenses, diaphragms etc.. Moreover, mirror elements or deflection means altering the beam travel length, such as mirrors arranged in the direction of the beam, may be utilized to alter the travel lengths of the radiation and thus simulate a movement.

In a second embodiment, there is, for example, neither a movement of the transmitting and receiving device nor of the object, and only the signal form received by the object, e.g. the time signal of the reflected radiation, is detected. This reflected signal, in terms of its width and form, is dependent upon the number of layers or sheets of the sheet-like object, since the signal portions reflected on these layers have different travel-back times to the receiving device and thus broaden the reflected signal e.g. in terms of time. On the basis of the width, it is then possible to determine the number of sheets or the thickness of the object. The reflected signal can be processed in various ways, as elucidated hereinbefore in connection with the previous embodiments, and can be compared to stored experimental values for reflected signals associated with different object thickness

values. By statistical evaluation of the signal form received and of signal forms, stored or determined or learned during operation, which are associated with different thickness values, the thickness of an object can be determined simply and rapidly.

The device for determining the thickness or the number of sheets of a moving sheet-like object or of a sheet-like object according to the present invention renders possible facilitated handling without operational elements. Software analysis of the characteristic signals, spectra, areas permits e.g. arbitrary accuracy, thereby increasing reliability to a high degree as well. The device of the present invention furthermore renders possible a simple construction, improved evaluation possibilities, is based on a non-contacting process and is flexibly applicable to various configurations, e.g. in paper manufacture, paper processing and paper handling. It may be employed e.g. in the utilization of microwave radiation with all sheet-like objects having a thickness between 1/10 mm and some millimeters.

Claims

1. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500), comprising:

a transmitting and receiving device (102; 202; 302; 402; 502) for transmitting radiation to the moving object (100; 200; 300; 400; 500), for receiving reflected radiation containing at least the part of the radiation transmitted to the object (100; 200; 300; 400; 500) that is reflected by the moving object (100; 200; 300; 400; 500), and for generating a signal representing the reflected radiation; and

an evaluation means (104; 204; 304; 404; 504) for determining the thickness of the moving object (100; 200; 300; 400; 500),

characterized in

that the evaluation means (104; 204; 304; 404; 504) receives the signal representing the reflected radiation, compares a signal pattern of the signal representing the reflected radiation to stored signal patterns for predetermined thickness values of the moving object (104; 204; 304; 404; 504) and determines the thickness of the moving object (104; 204; 304; 404; 504) as a function of said comparison.

2. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 400) according to claim 1, wherein the evaluation means (104; 404) further comprises:

a first storage means (106; 406a) for storing one or more previously determined time signal patterns each associated with a specific thickness of the moving object (100; 400); and

a first comparison means (108; 408a) for comparing the time signal pattern of the signal representing the reflected radiation to the stored previously determined time signal patterns and for determining the thickness of the moving object (100; 400) on the basis of the comparisons.

3. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 300; 400) according to claim 1 or 2, wherein the evaluation means (204; 304; 404) further comprises:

a transformation means (210; 310; 410) for transforming the time signal pattern of the signal representing the reflected radiation to the frequency domain in order to generate a frequency spectrum of the reflected radiation.

4. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 300; 400) according to claim 3, wherein the transformation means (210; 310; 410) carries out a Fourier transform.

5. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 400) according to claim 3 or 4, wherein the evaluation means (204; 404) comprises furthermore:

a second storage means (206; 406b) for storing one or more previously determined frequency spectra each associated with a specific thickness of the moving object (200; 400); and

a second comparison means (208; 408b) for comparing the frequency spectrum of the reflected radiation to the stored previously determined frequency spectra and for determining the thickness of the moving object (200; 400) on the basis of the comparisons.

6. A device for determining the thickness or the number of sheets of a moving sheet-like object (300; 400) according to any of claims 3 to 5, wherein the evaluation means (304; 404) comprises furthermore:

a third storage means (206; 406b) for storing one or more previously determined area values each associated with a specific thickness of the moving object (300; 400);

an area determination means (312; 412) for determining the area of the spectrum around the frequency corresponding to the Doppler shift of the frequency of the radiation transmitted to the moving object (300; 400); and

a third comparison means (308; 408c) for comparing the area determined to the stored, previously determined area values and for determining the thickness of the moving object (100) on the basis of the comparisons.

7. A device for determining the thickness or the number of sheets of a moving sheet-like object (500) according to any of the preceding claims, comprising furthermore a reflector (516) which, with respect to the transmitting and receiving device (502), is disposed behind the moving object (500) and which reflects the radiation transmitted through the moving object (500) to the moving object (500) and to the transmitting and receiving device (502).

8. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400) according to any of the preceding claims, wherein the first, second and/or third comparison means (108; 208; 308; 408a, b, c) comprise a fuzzy logic.

9. A device for determining the thickness or the number of sheets of a moving sheet-like object (400) according to any of the preceding claims, wherein the first, second and/or third comparison means (408a, b, c) are coupled to a fourth comparison means (414) for examining the conformity of the thicknesses determined by the comparison means (408a, b, c) and for determining a most probable thickness of the object (400).

10. A device for determining the thickness or the number of sheets of a moving sheet-like object (400) according to claim 9, wherein the fourth comparison means (414) is a fuzzy logic.

11. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500) according to any of the preceding claims, wherein the radiation is electromagnetic or acoustic radiation.

12. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500) according to claim 11, wherein the radiation is microwave radiation.

13. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500) according to claim 11 or 12, wherein the transmitting and receiving device (102; 202; 302; 402;

502) comprises a waveguide antenna (118; 218; 318; 418; 518).

14. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500) according to claim 11, wherein the radiation is ultrasonic radiation.

15. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200, 300; 400; 500) according to any of the preceding claims, wherein the moving object (100; 200; 300; 400; 500) is a moving stack of sheets and the thickness of the moving stack of sheets is a measure for the number of media.

16. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500) according to claim 15, wherein the moving stack of sheets is a stack of paper.

17. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400; 500) according to any of the preceding claims, wherein the transmitting and receiving device (102; 202; 302; 402; 502) is in motion instead of the object.

18. A device for determining the thickness or the number of sheets of a sheet-like object (100; 200; 300; 400; 500), comprising

a transmitting and receiving device (102; 202; 302; 402; 502) for transmitting radiation to the object (100; 200; 300; 400; 500), for receiving reflected radiation containing at least the part of the radiation transmitted to the object (100; 200; 300; 400; 500) that is reflected by the object (100; 200; 300; 400; 500), and for

generating a signal representing the reflected radiation; and

an evaluation means (104; 204; 304; 404; 504) for determining the thickness of the object (100; 200; 300; 400; 500),

characterized in

that the evaluation means (104; 204; 304; 404; 504) receives the signal representing the reflected radiation, compares a signal pattern of the signal representing the reflected radiation to stored signal patterns for predetermined thickness values of the object (104; 204; 304; 404; 504) and determines the thickness of the object (104; 204; 304; 404; 504) as a function of said comparison.

19. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 400) according to claim 18, wherein the evaluation means (104; 404) further comprises:

a first storage means (106; 406a) for storing one or more previously determined time signal patterns each associated with a specific thickness of the object (100; 400); and

a first comparison means (108; 408a) for comparing the time signal pattern of the signal representing the reflected radiation to the stored previously determined time signal patterns and for determining the thickness of the object (100; 400) on the basis of the comparisons.

20. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 300; 400) ac-

cording to claim 18 or 19, wherein the evaluation means (204; 304; 404) further comprises:

a transformation means (210; 310; 410) for transforming the time signal pattern of the signal representing the reflected radiation to the frequency domain in order to generate a frequency spectrum of the reflected radiation.

21. A device for determining the thickness or the number of sheets of a moving sheet-like object (200; 400) according to claim 20, wherein the evaluation means (204; 404) comprises furthermore:

a second storage means (206; 406b) for storing one or more previously determined frequency spectra each associated with a specific thickness of the object (200; 400); and

a second comparison means (208; 408b) for comparing the frequency spectrum of the reflected radiation to the stored previously determined frequency spectra and for determining the thickness of the object (200; 400) on the basis of the comparisons.

22. A device for determining the thickness or the number of sheets of a moving sheet-like object (100; 200; 300; 400) according to any of the preceding claims, wherein the first and second comparison means (108; 208; 408a, b) comprise a fuzzy logic.

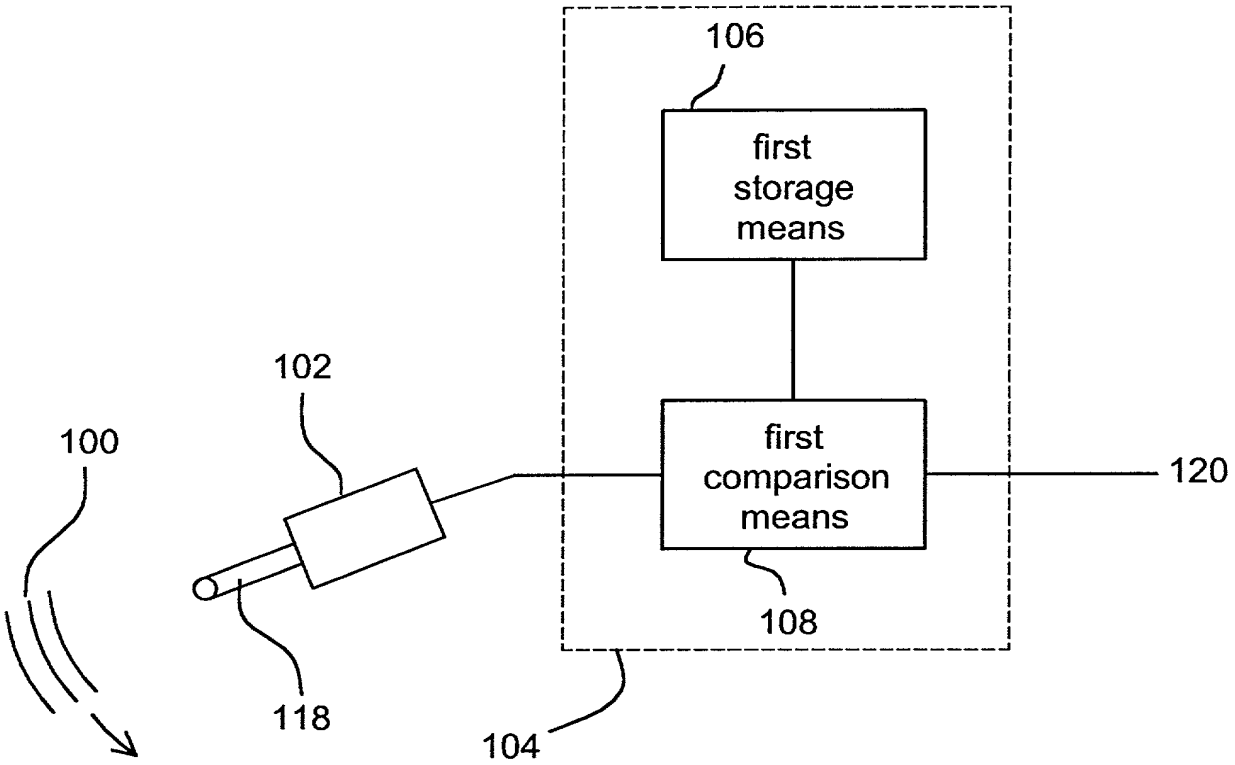
106
first storage means
102
100
first comparison means
120
108
118
104

Fig. 1

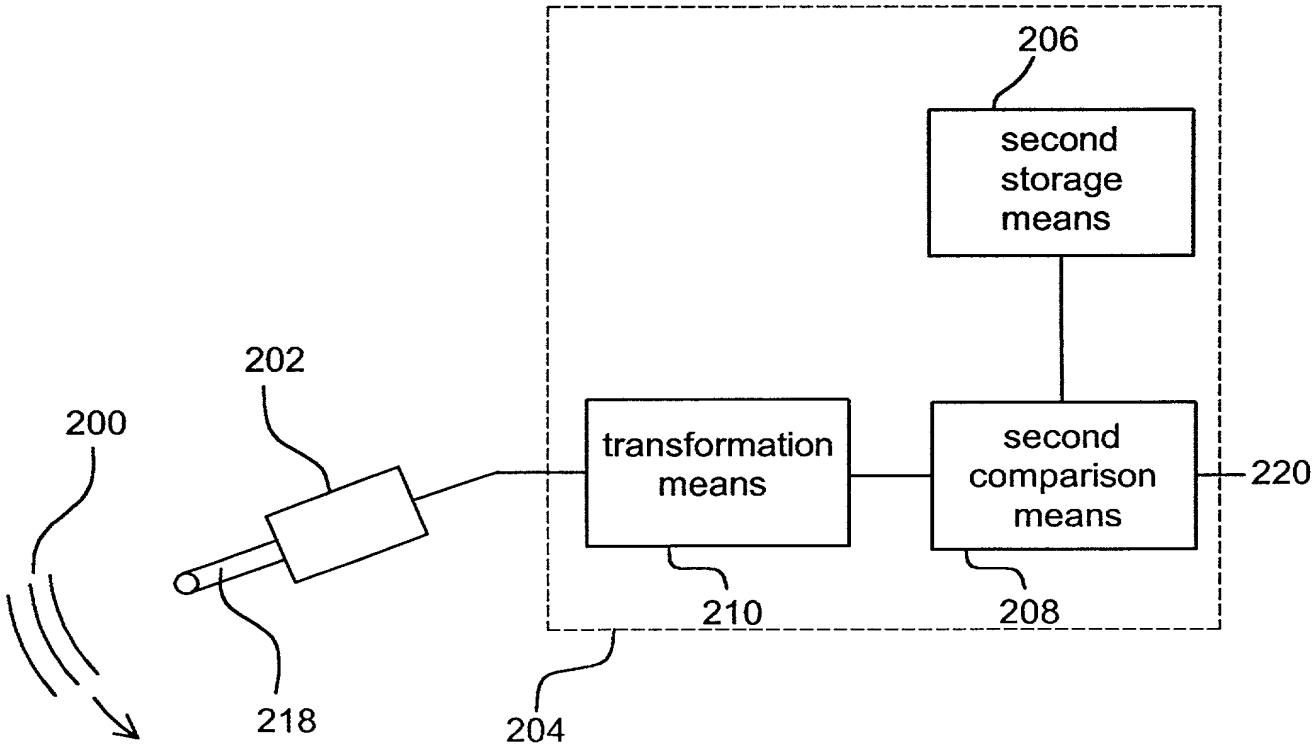
206
second storage means
202
200
transformation means
second comparison means
220
210
208
218
204

Fig. 2

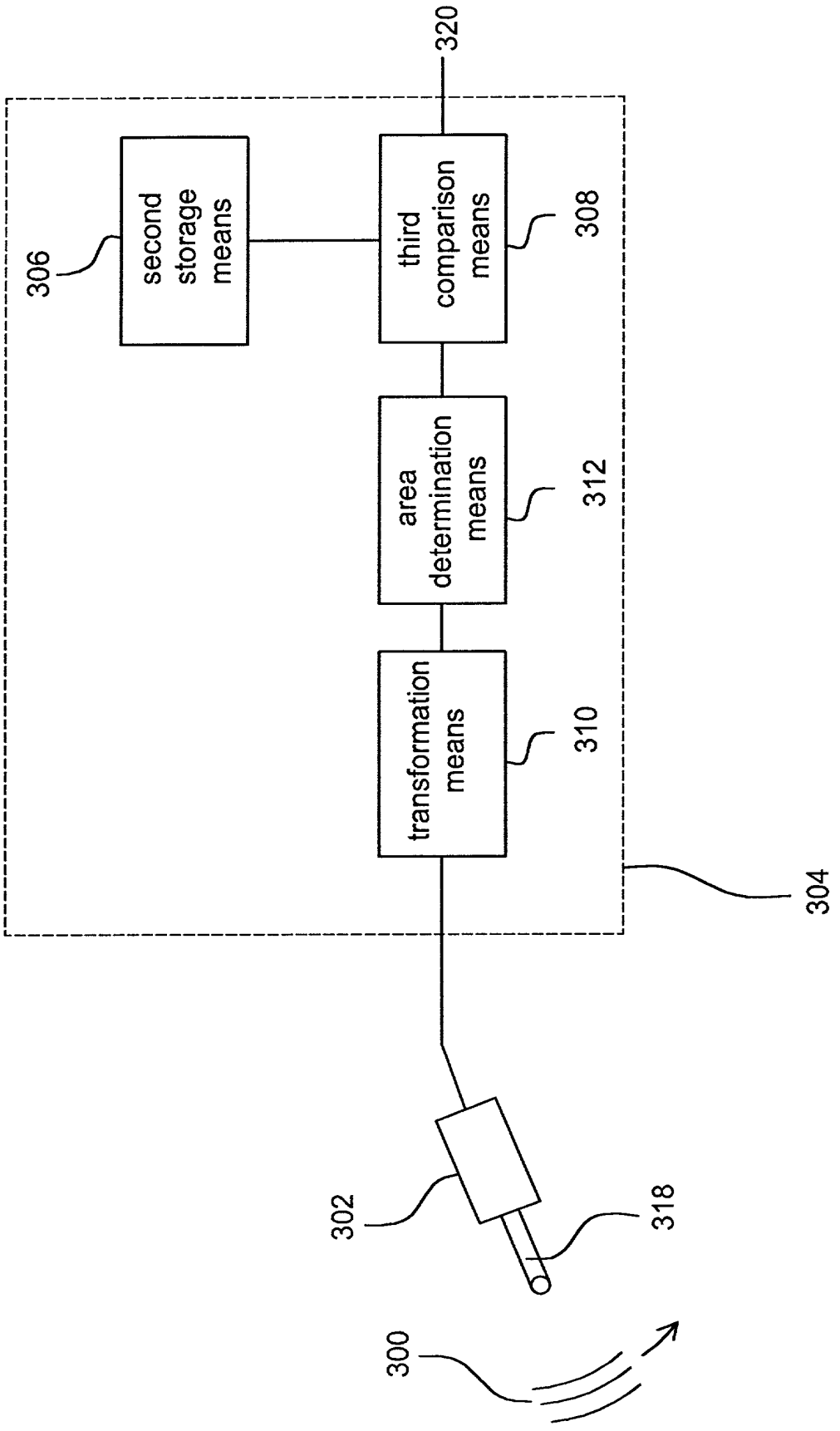
320
second storage means
306
third comparison means
308
area determination means
312
transformation means
310
304
302
318
300

Fig. 3

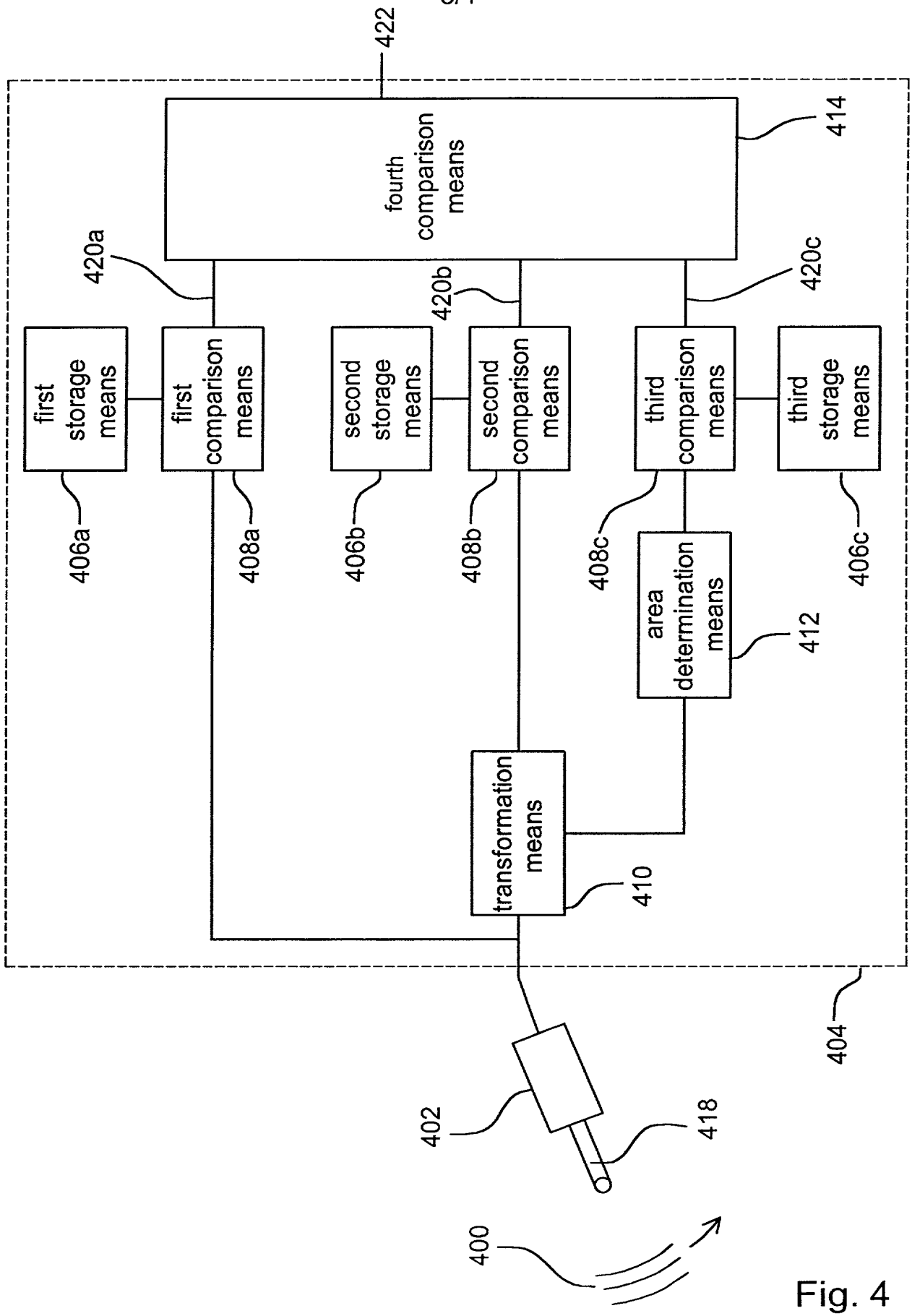
422
fourth comparison means
414
420a
420b
420c
first storage means
first comparison means
second storage means
second comparison means
third comparison means
third storage means
406a
408a
406b
408b
408c
406c
area determination means
412
transformation means
410
404
402
418
400

Fig. 4

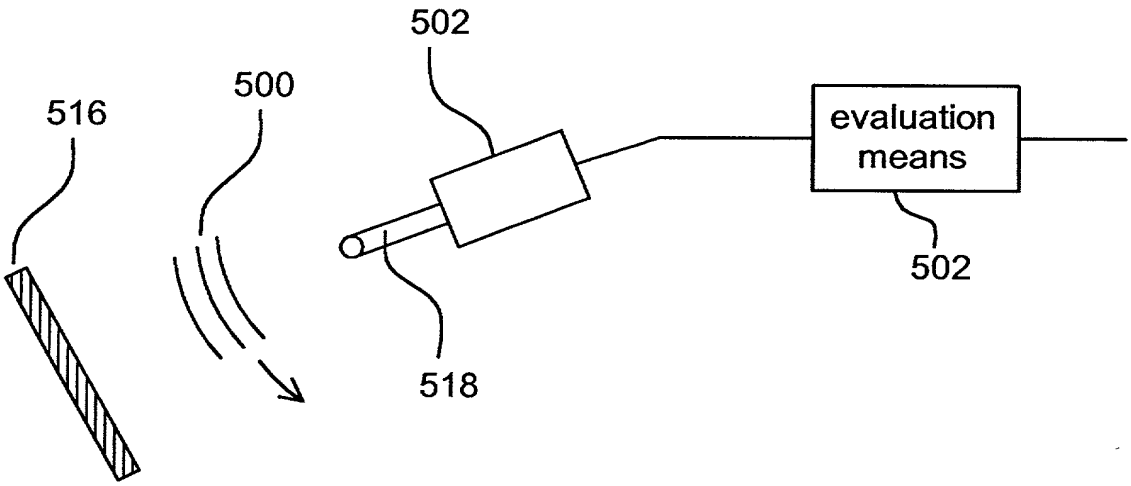

Fig. 5

Practitioner's Docket No. 13189.143 *PATENT*

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL, CONTINUATION, OR C-I-P)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is for a national stage of PCT application.

INVENTORSHIP IDENTIFICATION

My residence, post office address and citizenship are as stated below, next to my name. I believe that I am the original, first and sole inventor of the subject matter that is claimed, and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

Device for Determining the Thickness or the Number of Sheets of a Sheet-like Object

SPECIFICATION IDENTIFICATION

The specification was described and claimed in PCT International Application No. PCT/EP00/04264 filed on May 10, 2000.

ACKNOWLEDGMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information, which is material to patentability as defined in 37, Code of Federal Regulations, Section 1.56, and which is material to the examination of this application, namely, information where there is a substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent.

PRIORITY CLAIM (35 U.S.C. Section 119(a)-(d))

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

Such applications have been filed as follows.

PRIOR PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. SECTION 119(a)-(d)

INDICATE IF PCT	APPLICATION NUMBER	DATE OF FILING DAY, MONTH, YEAR	PRIORITY CLAIMED UNDER 35 U.S.C. SECTION 119
PCT	PCT/EP00/04264	10/May/2000	yes

PRIOR FOREIGN APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. SECTION 119(a)-(d)

COUNTRY	APPLICATION NUMBER	DATE OF FILING DAY, MONTH, YEAR	PRIORITY CLAIMED UNDER 35 U.S.C. SECTION 119
Germany	199 22 125.1	12/May/1999	yes

POWER OF ATTORNEY

I hereby appoint the practitioner(s) associated with the Customer Number provided below to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

Customer No. 24283

SEND CORRESPONDENCE TO
Customer No. 24283

DIRECT TELEPHONE CALLS TO:
Carl A. Forest
303-379-1114

DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE(S)

Inventor's signature Marion Griebel

Typed Inventor's Full Name: Marion GRIEBEL

Date October 4, 2001 **Country of Citizenship** German

Residence (City, Country) D-86179 Augsburg, Germany

Post Office Address Tattenbachstr. 20 d

D-86179 Augsburg, Germany DEX

Inventor's signature _____

Typed Inventor's Full Name: _____

Date _____ **Country of Citizenship** _____

Residence (City, Country) _____

Post Office Address _____

_____